

1  
Ag 84Ah  
cap. 3

DC BRANCH -1)

# HIGH-DENSITY APPLE ORCHARDS— PLANNING, TRAINING, AND PRUNING

Agriculture Handbook No. 458

U.S. DEPT. OF AGRICULTURE  
NATIONAL LIBRARY  
SERIALS  
FEB 7 1975

FEB 7 1975

Agricultural Research Service  
UNITED STATES DEPARTMENT OF AGRICULTURE

## CONTENTS

	<i>Page</i>
Introduction .....	1
Background and purpose .....	1
The problem—future demands .....	2
Production per unit area .....	2
High-quality fruit .....	3
Efficient use of labor .....	3
Central leader trees for high-density orchards—a possible solution .....	3
High-density plantings .....	3
High-density orchards defined .....	4
Characteristics of individual trees—the central leader tree .....	4
Management methods in high-density plantings .....	8
Basic planting design .....	8
Importance of size control and methods used .....	9
Training and pruning methods in high-density orchards .....	10
Training system for developing central leader trees .....	22
Renewing old orchards to high-density orchards .....	30
Selecting the site .....	32
Application of size-control pruning to existing orchards of moderate to standard density .....	32

# HIGH-DENSITY APPLE ORCHARDS—PLANNING, TRAINING, AND PRUNING

By DON R. HEINICKE, *horticulturist, Agricultural Research Service, Wenatchee, Wash.*

## INTRODUCTION

The introduction of high-density apple orchards may well be one of the most important changes in apple production practices. These orchards are capable of producing early and sustained yields of quality fruit. High-density orchards will provide for an efficient operation with the optimum utilization of the available labor force. Reaching these goals will mean the difference between success and failure.

High-density orchards should not be considered as a work-free system of producing fruit. Much has been written of the values of size-controlling rootstocks, spur-type scions, training and pruning methods, mechanical devices, and miracle chemicals to be used in these plantings. As a result, orchards that average 1,000 to 1,500 boxes per acre are considered failures because 2,000 to 3,000 were expected. Where peak yields are not reached until the sixth to eighth year, the grower is disappointed because he expected them in the third or fourth year. A high input of labor and materials in the early years of these or-

chards is unacceptable to some because they expected a work-free system.

Much money, skill, and physical labor are needed to develop a producing orchard. There are few shortcuts. The advantage of high-density plantings is that the orchard space can be rapidly filled, fruited, and then maintained by utilizing the early bearing and size-controlling characteristics of certain stock-scion combinations. Available labor supplies can be developed to do the specialized training necessary to position limbs for the production of quality fruit. The total product of this effort is an orchard that can be operated efficiently and produce high yields of quality fruit early and throughout the life of the orchard.

Certain practices can mean the difference between a successful and unsuccessful operation. In developing a successful program, these questions must be answered: *What* is to be done? *Why* must it be done? *How* is it done? *Who* does the job? *When* should the program be started?

## BACKGROUND AND PURPOSE

To keep up with the pace of today and the challenges of tomorrow, orchard practices must be changed. To determine what type of changes are needed, the requirements and problems of the future must be understood. The grower will be faced with the problems of: (1) Increased general costs of production, (2) the demand for higher quality fruit, and (3) labor shortages. For the grower to survive these problems, he must have an efficient orchard operation, which means: (1) High production per unit

area of orchard, which must occur early in the life of the orchard; (2) quality fruit that can be readily marketed; and (3) efficient use of labor in all operations. To accomplish this, each tree must be an efficient, easily managed unit utilizing to the limit the climatic and cultural factors available for the economic production of quality fruit. The purpose of this handbook is to help the grower understand the full implications of these changes and to enable him to deal with this new situation.

## THE PROBLEM—FUTURE DEMANDS

### PRODUCTION PER UNIT AREA

Apple production is controlled by certain limiting factors, which fall into three groups: Varietal, cultural, and climatic. The grower has control over the selection of the variety to be grown. Varietal selections are based on the adaptability of the variety to a particular site, tree characteristics, yield, and marketability of the fruit. Cultural factors are also within the control of the grower and can be changed to fit individual circumstances and to incorporate new methods. Climatic factors, particularly light and temperature, are factors that can be utilized but over which we have little control. These factors, which usually limit the productivity of fruit trees in good orchards, are the factors that we must learn to fully utilize.

It has been said, and rightly so, that the shade a tree casts upon itself is the most important factor limiting its productivity. One solution to this problem is to reduce self-shading and to develop trees that have a maximum amount of foliage exposed to sunlight. In this way, the available sunlight will be more fully utilized.

Studies of light penetration into apple trees indicate a definite shell or layer structure in regards to light penetration (fig. 1). A layer of foliage and fruit on the outside surface of the tree receives a high proportion of the available light far in excess of tree requirements. A second layer further down has adequate light, and a third layer or core in the center of the tree has insufficient light for the production of quality fruit. The solution to greater productivity lies in eliminating the unproductive area of inadequate light, which will improve the overall efficiency of that area of the orchard occupied by a tree.

The use of small trees is one means of reducing or eliminating the unproductive shaded centers of trees. Studies have indicated that as tree size decreases the shaded unproductive area also decreases. The amount of shaded foliage decreases from 24 to 19 to 13 to 8 percent, respectively, as tree size was reduced from

20-foot-high standards to 16-foot semistandards to 12-foot semidwarf to 8-foot dwarfs. On the basis of total leaf area per acre exposed to adequate light, the standard trees in the orchard studied had only 120,000 compared with 180,000 square feet of foliage per acre for the dwarf trees. Dwarf trees, with half again as much adequately exposed foliage as standard size trees, have a greater potential productivity capacity. In effect, the unproductive shaded centers of the large trees are eliminated by using smaller trees. With smaller trees, only the highly productive treetops remain in the orchard.

Small trees have a greater surface area in relation to their volume than larger trees and present a higher percentage of foliage to sunlight. However, planting smaller sized trees does not insure good light penetration. Tree shape as well as size is also important as it influences the surface area of the tree and the distribution of shade in the tree. Trees must be developed of such size and shape that they provide the greatest unshaded leaf surface per area of orchard space occupied. This will require a radical change in many orchards. The old vase-shaped, open-center trees with the fruiting area 12 to 16 feet above ground will

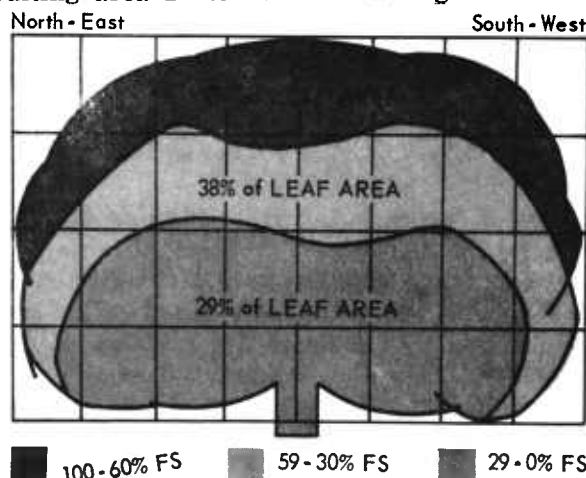


FIGURE 1.—Light penetration into tree canopies is influenced by foliage density. The outer and center layers receive adequate light while an inner core does not. Pruning and training should open the canopy to permit light to penetrate into the shaded area.

have to give way to the smaller, compact, pyramidal-shaped, central leader tree used in high-density plantings (fig. 2). The use of smaller trees means more trees per acre and this, alone, will improve the possibility of early high yields.



PN-3472

FIGURE 2.—Note the large size of trees in the old low-density planting. The new orchard of small trees will fruit well below these old trees. Note change in tree density.

### HIGH-QUALITY FRUIT

The quality of fruit is related to the exposure of the fruit to sunlight while still on the tree. Color is one of the primary factors determining the marketability of apples, and exposure to light is essential to color development. In relation to exposure to light, Red Delicious and McIntosh apples were found to be in three

groups. Highest color development was achieved where fruit had from 70 to 100 percent of full sun exposure. Adequate color for extra fancy grade fruit developed in from 50 to 70 percent of full sun, and fruit receiving less than 50 percent of full sun did not develop adequate color. Two other quality factors, size and soluble solids, also increased as the fruit and adjacent foliage were exposed to more sunlight while on the tree.

### EFFICIENT USE OF LABOR

Efficient use of labor and equipment for cultural operations is a daily concern of the grower. In the future, the lack of available labor may eliminate the ladder from the orchard. Growers will have to place the workers up in the fruiting area of the tree by mechanization—or bring the fruiting area down to the workers on the ground. An orchard that can be picked from the ground will be the easiest to mechanize but will also be the last to need mechanization.

Small trees confined to definite areas and shapes in high-density plantings will bring the fruiting area down to the worker and be more adaptable to mechanization. It may be more important to speak in terms of utilizing labor rather than labor saving. The total operation must be considered. The most critical labor problems are involved in harvest due to the short time period involved. If labor can be utilized over a longer time period for operations, such as pruning and training the trees, more permanent labor may be available at harvest and the total operation will be more efficient.

## CENTRAL LEADER TREES FOR HIGH-DENSITY ORCHARDS— A POSSIBLE SOLUTION

### HIGH-DENSITY PLANTINGS

The use of smaller than standard sized trees of uniform shape in high-density plantings of from 200 to 500 or more trees per acre may be a solution to the problem of developing more efficient orchard operations (fig. 3). Trees in

these plantings will require some type of size control, which can be accomplished in many ways. The oldest method involves pruning and the control of fertilizers; the most popular method is to use size-controlling rootstocks and spur-type scion varieties. All these methods have certain advantages and limitations. No one

method will solve the problems of all growers. Integrated programs must be developed using these methods and others yet to be found. By a combination of methods tree size can be controlled and higher yields of better quality fruit obtained more efficiently.

### HIGH-DENSITY ORCHARDS DEFINED

Dense orchards can develop regardless of tree spacing. The wider the spacing the longer the time required for this to occur. The degree of planting density, whether low, moderate, high, or ultra high, can be rated by the time it takes to reach the ultimate production potential of the orchard. This is determined by tree vigor, early bearing characteristics, and the number of trees planted per acre.

For purposes of this handbook, the density of orchards is defined as follows:

<i>Density</i>	<i>Number of trees per acre</i>	<i>Years to reach full production</i>
Low -----	< 100	15 to 20
Moderate or standard ----	100 to 200	9 to 15
High -----	200 to 500	6 to 9
Ultra high -----	> 500	4 to 7

Many growers recognized the advantages of increasing tree density and planted new orchards at tree spacings much closer than practiced in the past (fig. 3). The problem today is that trees in these plantings are still being handled (training and pruning) as trees were in less dense plantings. An additional problem is that adequate size control is not provided, and the trees outgrow their limited space. To

plant a high-density orchard involves more than planting more trees per acre. One has to apply special techniques in maintaining them at the closer spacing.

### CHARACTERISTICS OF INDIVIDUAL TREES— THE CENTRAL LEADER TREE

The whole idea of high-density plantings requires that each tree have a small set space to occupy. If trees are allowed to spread out into the row, the advantage of convenience they offer is lost. These characteristics hold true for individual or hedgerow trees.

Trees in high-density orchards should have a maximum number of fruiting branches and a minimum number of structural branches. Fruiting branches are best developed and maintained as horizontal branches. The best structure for high-density trees is an upright central post, called the central leader, surrounded by near-horizontal fruiting branches. These branches should be so arranged and sized that each branch casts a minimum amount of shade on other branches.

Several conditions must be met if high-density plantings are to be successful: Upright growth cannot be tolerated in high-density plantings (fig. 4). Upright growth is slow to come into bearing, and once it does the fruit pulls the upright limbs down into the work row or into the adjacent trees. In low-density plantings, the tree is often allowed to grow upright for many years and finally is spread by the fruit load into a horizontal position. In high-density plantings, waiting for the crop to do the spreading is unacceptable.

An apple tree should be composed of horizontal fruiting laterals maintained up to a sufficient height to obtain a maximum amount of fruiting wood per orchard unit (fig. 5). To hold the laterals in position and obtain the proper distribution, the laterals need to be maintained on a central trunk or leader of the tree (fig. 6).

Individual laterals along the central leader will have to be smaller, more closely spaced, and more numerous than on the standard orchard tree in the Pacific Northwest. However,



FN-3025

FIGURE 3.—Typical high-density plantings contain from 200 to 500 trees per acre.

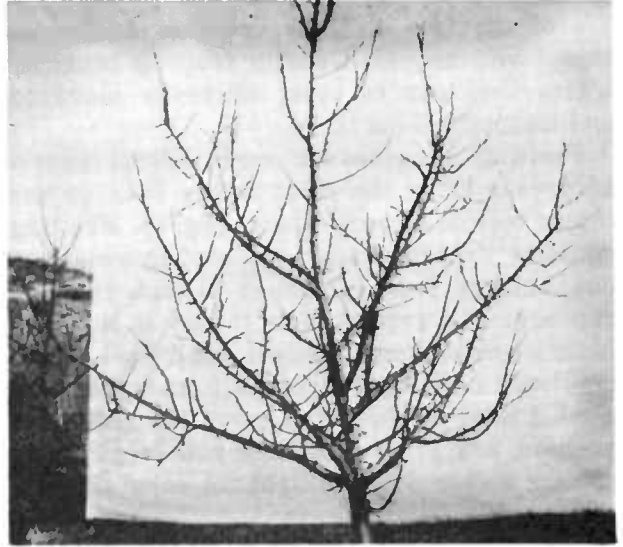
care must be taken not to allow too many branches to develop, or heavy cuttings will be required later.

Trees will be rather narrow; therefore, fruiting branches should be maintained well down

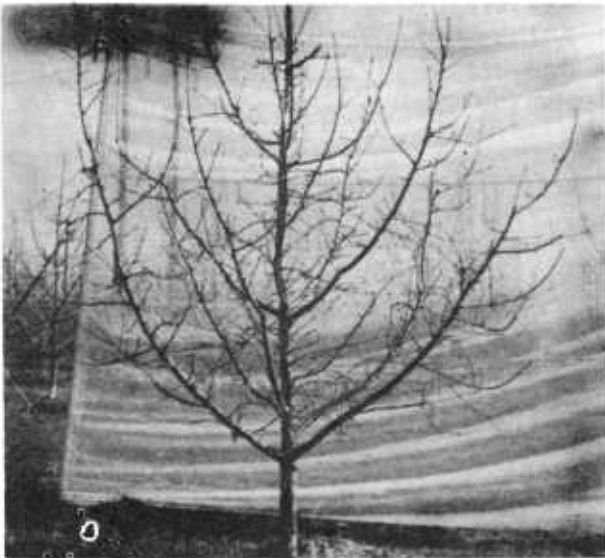
the limbs and close to the central leader rather than at the ends of the limbs (fig. 7). These fruiting branches should be developed as the tree grows, not after it reached its full size. To eliminate the need to prop these lateral



**FIGURE 4.**—Upright limbs in these trees have little lateral branching, poor fruit set, limb rubbed fruit where set does occur, and considerable vegetative extension. PN-3473



**FIGURE 5.**—Spread tree. Branches in a position slightly above horizontal develop side branches, set fruit well, carry the fruit without limb rub, and have less vegetative extension than upright branches. PN-3474



**FIGURE 6.**—The central leader tree has the central stem and horizontal fruiting branches. Fruiting branches are spaced so they do not interfere with each other each being smaller than the one below it. PN-3475



**FIGURE 7.**—Inner portion of central leader tree. Central leader trees will be rather narrow fruiting right to the center. Maintenance of this fruiting characteristic is dependent upon having light penetration into the center of the tree. PN-3476

branches, they will have to be stiff enough to carry the fruit load (fig. 8).

A system of permanent fruiting branches should be developed and maintained. There should be as little change of position of these branches as possible both during the season as the crop weight increases and through the life of the tree as these branches are maintained or renewed. Develop fruiting branches where they can be most efficiently managed and maintain them there.

Fruiting branches on each lateral should be developed on the sides rather than on the top or bottom of each lateral (fig. 9). Fruiting spurs on the top of a branch become too vigorous, and the fruit is subject to limb rub and sunburn. Fruiting spurs on the lower side of a branch are weak and produce small fruit. Those developed from the side of the branch maintain a good level of vigor and carry the fruit in a position less subject to limb rub or sunburn, yet are well exposed to light for color and size development.

The shape of the tree should be pyramidal or cone shaped. Tree height should be about one and a half times its diameter or width at the base. Trees lend themselves to growth in these proportions, and the resulting fruiting areas can be easily reached for harvesting. The tree should be smaller at the top than at the bottom to provide for good light penetration. Within this tree shape, the aim is to develop a system

of permanent fruiting branches to produce consistent crops of high-quality fruit.

Several physiological and physical differences between upright and horizontal branches should be noted (fig. 10). Upright growth is characterized by strong, vigorous, vegetative shoots with narrow branch angles. Horizontal shoots are weaker, less vegetative, and more fruitful. The large amount of vegetative extension on upright shoots makes control of tree size difficult and also interferes with fruit set. The weaker growth produced on horizontal branches is more easily controlled in high-density plantings when the allotted space for each tree is filled. Upright growth continues late into the season, which makes it more susceptible to early season freezes. Horizontal growth, on the other hand, matures earlier in the season as indicated by leaf drop. This may be an indication of earlier fruit maturity as well. Fruit set on horizontal branches is more consistent and responds to chemical thinning more uniformly than does fruit on upright growth. Because of the position in which the apple is held, less sunburn and limb rub occur on fruit borne on horizontal rather than on upright growth.

To develop favorable characteristics, one should follow these simple rules:

1. Prevent upright growth (fig. 4).
2. Develop horizontal laterals (fig. 5).
3. Space small laterals along the central leader (fig. 6).

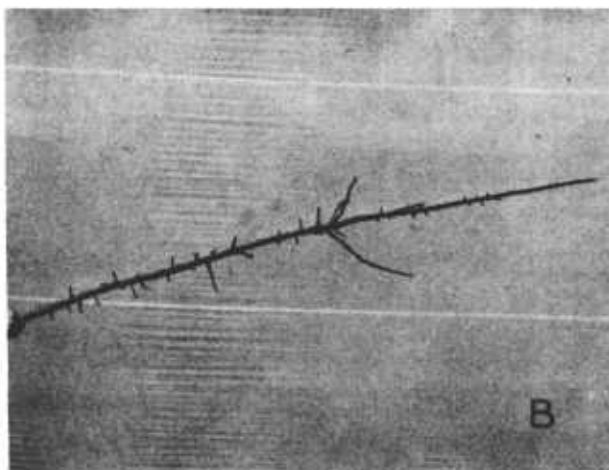
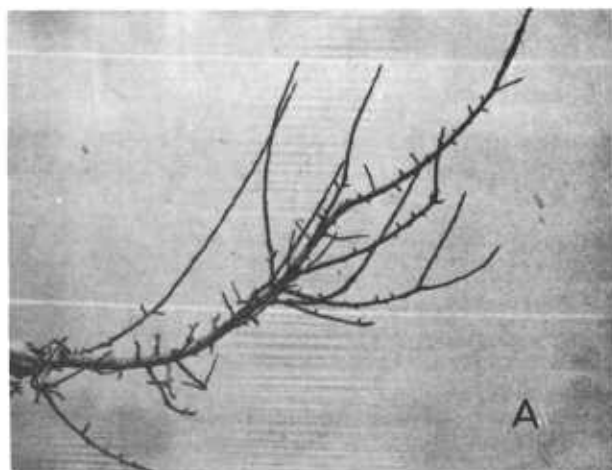
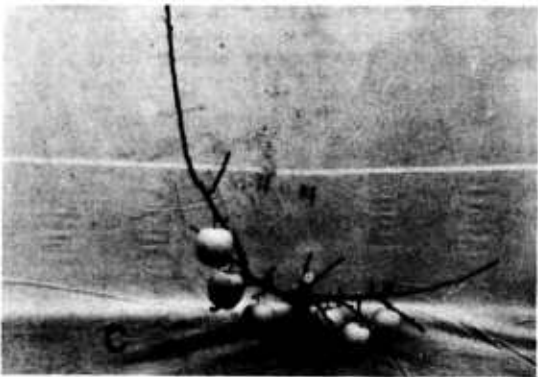
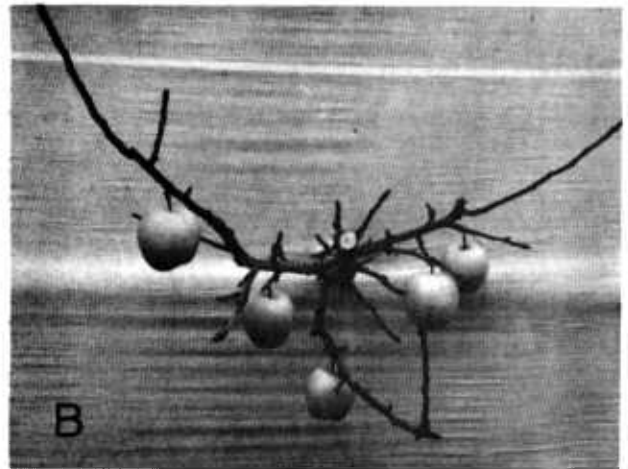
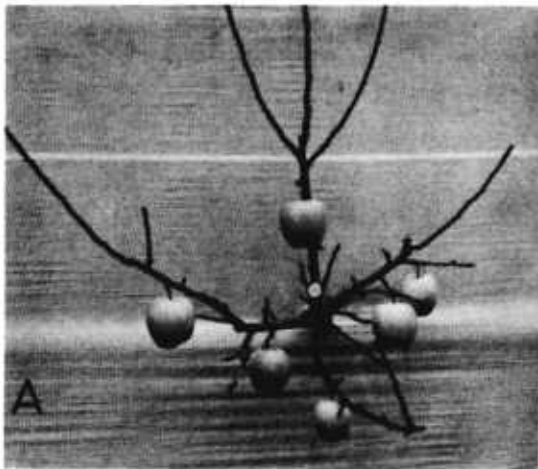


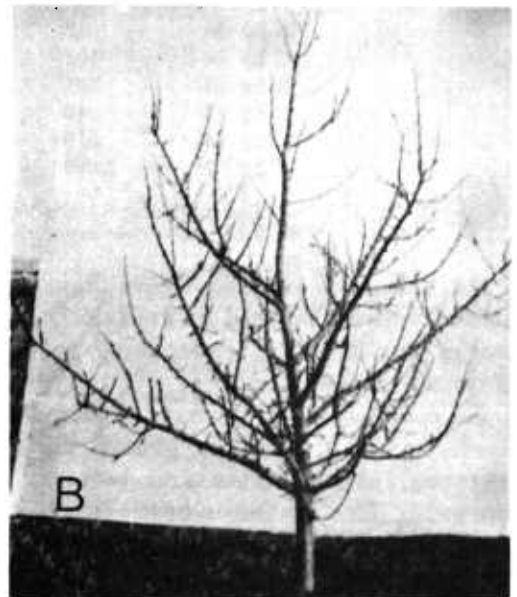
FIGURE 8.—Major lateral branches. A, Horizontal branches that are headed develop side shoots. B, Unheaded branches are long, require support, and develop fewer side shoots.

FN-3477/FN-3478





PN-3479/PN-3480/PN-3481  
**FIGURE 9.**—Developing fruiting branches. *A*, Fruiting branches can develop from limbs in all directions. Branches arising from either side of the limb are ideally located. Fruit on these side branches hang free and are protected from limb rub, wind damage, and sunburn. *B*, In pruning, remove all upright shoots; do not let them develop. *C*, Hangers arising from the bottom of the limbs can be maintained for several years on young trees but should be removed when they begin to weaken.



PN-3482/PN-3483  
**FIGURE 10.**—Effect of limb spreading. *A*, limbs on the upright tree have not produced side branches for the development of fruiting spurs because of their crowded position. *B*, The tree with spread branches has intercepted more light, developed more fruiting spurs, and carried larger crops of quality fruit.

4. Develop and maintain fruiting spurs along entire branch as it develops (fig. 7).

5. Develop rigid, strong, self-supporting laterals (fig. 8).

6. Maintain fruiting branches in one position (fig. 8).

7. Develop fruiting spurs along the sides rather than top or bottom of lateral branches (fig. 9).

## MANAGEMENT METHODS IN HIGH-DENSITY PLANTINGS

### BASIC PLANTING DESIGN

Tree arrangement within the planting greatly influences the future working conditions within the orchard. Decisions must be made on irrigation systems, methods of spraying, soil management, and harvest before the planting design is selected. Basically, a combination of productivity, convenience, and efficiency is desired.

Tree density is the most important factor influencing early production. Regardless of the planting design used, enough trees should be planted per acre to rapidly fill the orchard space. Examples of several spacings and required yields per tree to reach certain production goals follow.

directions. Rectangular spacing may be as 2 by 3 or 1 by 2 plantings. In the 2 by 3 system, the trees are two units apart between trees (that is,  $5 + 5 = 10$ ) and three units apart between rows (that is,  $5 + 5 + 5 = 15$ ) for a 10 by 15, 12 by 18, or other similar spacings. Trees in this system (1) develop into hedgerows of individual trees with work limited to one direction, (2) conserve more space than the 1 by 1 planting, and (3) utilize more trees per acre, which promotes early yields per acre. Rectangular plantings are also planted using a 1 by 2 spacing in which trees are one unit apart in the row and two units between rows. This spacing results in a hedgerow system of 6 by 12, 8 by 16, or others. It is best used with

Tree spacing (units)	Number of trees per acre	Yield (in boxes) required per tree based on yield per acre in boxes of			Years required to reach expected yield
		1,000	1,500	2,000	
30 by 30	48	20.8	31.2	41.7	15 to 20
18 by 24	101	9.9	14.8	19.8	12 to 16
12 by 18	201	5.0	7.5	10.0	7 to 12
8 by 16	340	2.9	4.4	5.9	5 to 10
6 by 14	519	1.9	2.8	3.8	4 to 8
5 by 7 <sup>1</sup>	1,037	.5	.9	1.9	3 to 5

<sup>1</sup> Bed planting—trees are planted in 5 by 7 units in beds 35 feet wide. A 12-foot work row separates each bed.

As trees are planted closer together, more attention must be paid to the selection of rootstocks and training procedures to make the planting successful.

Several types of orchard spacings can be used. In the 1 by 1, or square planting, the distance between trees and between rows is the same. This system is best adapted to larger trees since the space between trees must be great enough to provide work space. These plantings are the least conserving of space but provide the convenience of work rows in both

smaller trees in which extreme size control has been utilized by the combination of stock and scion. With this system, a great deal of space is used as work rows and excessive row travel is necessary when spraying the orchard. Where trees of extremely small size are used, multiple row or bed systems might be used. With this method, it is as if the entire block were set very close without work rows, then work areas are cut through the orchard. It may develop into a bed of trees 35 feet wide, planted 5 by 7 feet, between work areas 10 to

12 feet in width. These plantings result in extremely high tree density that promotes early yield. By having a work area only every 20 to 40 feet, little space is lost and travel time for equipment is greatly reduced. Special equipment techniques will be necessary in spraying, soil management, and harvest, but these costs could be offset by the added productivity and efficiency of these plantings.

None of these systems should be absolutely rigid; row and tree spacings should be changed to fit individual circumstances.

### IMPORTANCE OF SIZE CONTROL AND METHODS USED

One factor, control of tree size, stands out above all others as the key to successful high-density plantings. The grower must provide several methods of size control adequate to control the trees in his planting. This lack of size control has been the fault in most orchards where these plantings have not proved successful. Many methods of size control are available. They can be classed as environmental, genetic, and cultural and should be considered in the early planning stage of the orchard.

Climatic factors, particularly the length of the growing season, have the final influence on

controlling tree growth. Although we cannot control these factors, knowledge of them will aid in planning. Long growing seasons or more favorable conditions for plant growth during the growing season increase the need for, but reduce the effectiveness of, size-controlling methods. The site on which the tree grows, particularly soil conditions, influences the selection and effectiveness of size-controlling factors.

The most satisfactory and essential method of size control is by the selection of plant material. Size-controlling rootstocks are available that can produce a tenfold difference in final tree size. These rootstocks have been selected not only on the basis of size control but also for their ability to bring the scion variety into early bearing. Although some size control may be gained through the use of selected seedlings, such as Antonovka and Beautiful Arcade, these trees would still be classed as standard sized trees. The size-controlling stocks now in use are clonal stock, which are vegetatively propagated. These stocks have been collected, developed, and classified at the East Malling Research Station, Maidstone, England. Numbers have been assigned to designate each rootstock; they do not indicate the degree of dwarfing.

Tree size is predictable in relation to rootstock according to the following table:

<i>Size</i>	<i>Rootstock</i>	<i>Anchorage</i>	<i>Soil adaptability</i>
Full size (standard)	Seedling	Very good	All types.
	MM 104	----do----	All types, avoid wet site.
Semistandard ( $\frac{3}{4}$ standard)	MM 111	----do----	All types, tolerates dry or sandy soil.
	M 2	Good	Most soils adequate, avoid extremes of sandy, heavy, or wet soil.
	MM 106	Very good	All types, avoid wet site.
Semidwarf ( $\frac{1}{2}$ standard)	M 7	Good	Avoid light soils.
	M 26	Good to fair	Use on better soils, avoid extremely light soil.
Dwarf ( $\frac{1}{4}$ standard)	M 9	Fair to poor	Use on best soil, avoid light soil.
Extreme dwarf ( $\frac{1}{10}$ standard)	M 27	----do----	Use on best soil.

Scion variety and local conditions alter the size response. This classification holds for both nonspur and spur-type strains even though a full size spur-type tree may be only two-thirds to three-fourths the size of a full size nonspur tree.

The performance of size-controlling rootstocks on certain sites has been somewhat disappointing. Size classifications were developed in England under greatly different conditions and with different varieties. Soil, sunlight, temperature, length of growing season, and irrigation override the size-controlling influence of the available rootstocks to some extent. Add to that a vigorous growing variety like Red Delicious and the size rating is often changed completely, at least in the early life of the tree. Spur-type strains of both Red Delicious and Golden Delicious respond more to the dwarfing characteristics of the rootstocks than do nonspur Delicious.

One advantage of the size-controlling rootstocks is that they will grow vigorously during the first few years, making it possible to fill the orchard space rapidly. Following this period of rapid growth, the trees come into bearing, which slows down growth. This early fruiting characteristic is the main difference between trees on size-controlling and seedling rootstocks. Growth of trees on seedling roots is not greatly reduced following the onset of fruiting. Growers have often been too quick to decide that there is no size control associated with rootstocks. These decisions have been based upon observations of young trees. The major size-controlling influence may not become apparent on these trees until they are at least 10 years old.

The selection of the scion variety or strain also influences final tree size. Spur-type strains of several varieties are available. These produce trees that range in size from about one-half to three-fourths the size of nonspur strains of the same variety. Within any one variety, selected spur strains may provide different degrees of dwarfing. Unfavorable environmental factors reduce the growth of spur-type trees more than nonspur trees. Therefore, they should only be used under favorable growing conditions.

In areas of regular heavy cropping, few problems of size control develop. Early crops on these trees should be protected from frost. A crop of apples in the fourth to sixth year on extremely vigorous trees is much more important than just the value of the crop. At this time, significant size control can be initiated. If growth is not vigorous, early crops can have a stunting influence and dwarf the tree too much before the tree has adequately filled its allocated space. On these trees, the crop should be removed to encourage growth.

The use of permanent sod cover crops on most sites is a very effective aid to control tree growth. It is a two-crop system where both trees and sod are managed. In the early years, tree growth is favored over the sod. When tree structure is adequately developed, the heavy sod cover will slow tree growth, encourage fruiting, and improve fruit quality. It is best to start the sod early so it is well established when the trees come into bearing. Fall seeding at the end of the first growing season is very satisfactory.

Fertilizing should be considered along with the cover crop. Heavy nitrogen fertilization, which is essential in the early life of the tree, if continued, makes the control of tree size, the bringing of the tree into production, and the production of well-colored quality fruit very difficult.

Training and pruning are essential parts of a successful size control program. Efficient tree units are developed through the manipulation of shoot growth and positioning of limbs for uniform light exposure.

## TRAINING AND PRUNING METHODS IN HIGH-DENSITY ORCHARDS

### Tree Shape

Trees of many shapes can be developed. The object is to utilize the natural growing habit of the tree to form an orchard unit of maximum productivity. The most important factor to consider in tree shape is light. The ideal shape would have all leaves on the tree intercepting a maximum and equal amount of light. With a perfect distribution of light, vigor would be evenly distributed throughout the tree resulting

in fruit of uniform size, quality, and maturity. In addition, a large percentage of the light-intercepting leaf area should be close to the ground or at least in a position that will be easy to manage and harvest.

Basically, three shapes should be considered. These shapes can be seen as natural shapes in many unpruned native plants.

The simplest shape is that of a plate or disk exemplified by water lilies. This plant canopy is only one-leaf thick and is always oriented in a horizontal position as it floats on the water. These leaves are well exposed to light only during midday. The amount of light energy striking these leaves in the morning or afternoon, when the sun is low in the sky, is greatly reduced. Many of our crowded, flat-topped fruit trees are of this shape and offer a minimum amount of leaf surface exposed to the sun. To get maximum exposure from these trees, there must be a solid canopy of foliage in the orchard. To develop this type of canopy, it must be high so that many of the orchard operations can be performed below it. This high canopy makes cultural operations, such as harvesting and spraying, difficult.

Another shape is the globe or roundish canopy. This is common to many open-grown deciduous trees such as the hard maples. The round crown may be close to the ground or high above it depending upon the main stem as determined by tree density. Round canopies have two characteristics: First, the widest part of the canopy is at the center or higher. This results in the bottom portion being shaded out. Second, a shell of foliage on the periphery usually shades out the entire center. Many apple trees are allowed to develop in this manner. Fruit produced in the outer part of the canopy will be of good quality, but that within the canopy will lack color, size, and other quality factors.

A third tree shape, cone or pyramidal, is commonly found in our evergreen forests. These cone-shaped tree crowns are characteristic of trees grown at a high density in the northern temperate region. As natural tree spacing decreases or as lower latitudes are considered, these canopies become less conical and more round or even flat. Since apple or-

chards are generally found in the northern temperate region and are now being planted at higher densities, this tree shape should be considered. Most of the established fruit trees have been trained so that several cone-shaped branches originate from the main trunk. These trees may appear to be more or less round canopies, but light and work spaces have been maintained between the several branches. The degree to which these individual limbs are developed varies greatly from tree to tree and orchard to orchard. These trees usually have well-exposed leaf areas and have a very acceptable shape for low-density orchards.

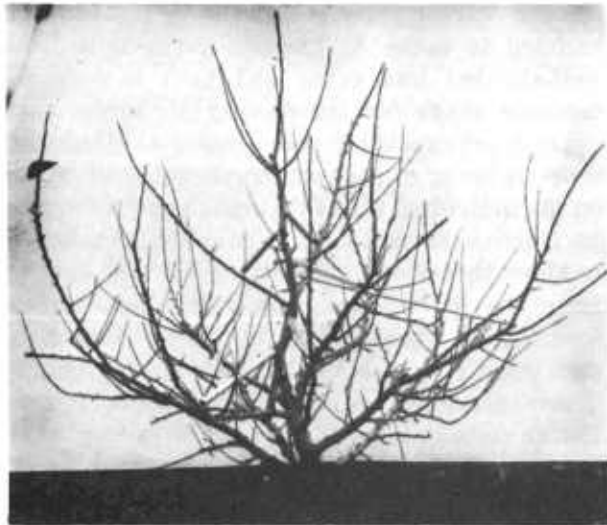
*Limb arrangement and number.*—When tree shape is being considered, emphasis must be put on the individual limbs that make up that shape. In Northwest orchards, a common practice is to allow three to five major scaffolds to develop from the main trunk. These in turn branch, forming an open, roundish canopy with light and work spaces between each major branch. These spaces are generally called ladder spaces, but an equally important function is to provide light passages through the tree. Thus, when properly handled, a round shape can be maintained without shading out the center of the tree.

In high-density plantings, it is important to develop the number of limbs that will complement the shape of tree desired. Usually, too many rather than not enough limbs are allowed to develop (fig. 11). Each limb should be positioned so that it has an area of its own to intercept light without casting excessive shade on the lower limbs. Space is also needed so that the fruit from each limb can hang free and not be subject to damage from limb rub.

Arrange limbs so that light passages are opened down into the tree. Do not try to plug all the holes in the top of the tree to intercept light. These windows in the treetop are vital to the maintenance of fruiting in the lower part of the tree. The development of limbs well spaced around the tree, no more than four or five for any complete rotation, is important. Each rotation of limbs can be located in one close whorl or spread vertically over some distance up the central stem (fig. 12).

The distance between limbs located one above

the other will depend upon ultimate tree size (fig. 13). The larger the tree, the greater the distance. Even in rather small trees, the distance between limbs directly above each other should be no less than 18 to 24 inches. Although such spacing may seem like a great distance in a young tree, it will soon be filled in and will prevent the need for excessive limb removal later. To fill the space, several rotations of limbs may be needed on each tree. As a result,



**FIGURE 11.**—Excess number of lateral limbs. It is usually a temptation with young trees to leave too many limbs. The first rule in constructive training is to remove all unnecessary shoots when they are 1 year old. FN-3484



**FIGURE 12.**—Branches arising from the central stem in whorls will not choke out the leader if they are suppressed by spreading. FN-3485

a tree may have from 10 to 20 individual limbs, all arising from the central leader. Each of these limbs should be maintained smaller than the limb directly below it to prevent excess shading. This type of pruning results in the pyramidal-shaped tree.

The lowest limbs should be started high enough on the trunk to facilitate necessary orchard operations such as weed or rodent control below them. If the first limb is located about 18 inches above the ground, the space is usually adequate. Limbs below this level interfere with spray booms and other implements. The height of these limbs should be regulated for each orchard operation.

*Limb position.*—Limb position, an essential factor related to fruiting, is often overlooked as trees are being developed (fig. 14). In any bearing orchard, the best fruiting occurs on the more horizontal branches. Individual branches can be spoken of as having an immature fruiting habit when in the upright position and a mature habit when they have attained a somewhat horizontal position. The old practice was to let limbs grow upright and unheaded. As a result of the upright position, they remained more vegetative and were slow to set fruit. Without heading they remained limber, and finally, the weight of the fruit brought them down out of the upright position.

In modern, **high-density** orchards, time cannot be allowed and space is not available for this natural fruiting down of the branches. To obtain early yields and to control growth, branches have to be physically spread. This can easily be accomplished by tying down the limbs with rope or twine or by using a spreader to physically brace the limb out from the central leader. Physically spreading the branches is particularly important if the pruning and training system involves heading cuts that stiffen the branches. If branches are headed and allowed to remain in the upright position, they soon stiffen permanently in that position.

The use of various physical means for spreading branches is not new. The extent to which it is needed in modern orchards has changed greatly. Most spreading in the past was concerned with developing wide, strong, crotch angles, whereas, today, interest is in limb posi-

tion. For structural strength and avoidance of winter injury, crotch angles should be wide and open, but the main concern should be with limb position. Good crotch angles are more important with larger trees. With smaller trees in high-density plantings, strong crotches are less important since each limb will be rather short and stiff and can be supported by tying to the central leader if necessary. Although

crotch angles are not of primary importance, only limbs with good angles should be selected and allowed to develop. All branches originating with poor angles should be removed as 1-year-old shoots. The point here is that the training program is often overlooked the first few years, and as a result many poor branches are allowed to grow. Rather than removing all these branches and starting over, often, they can be

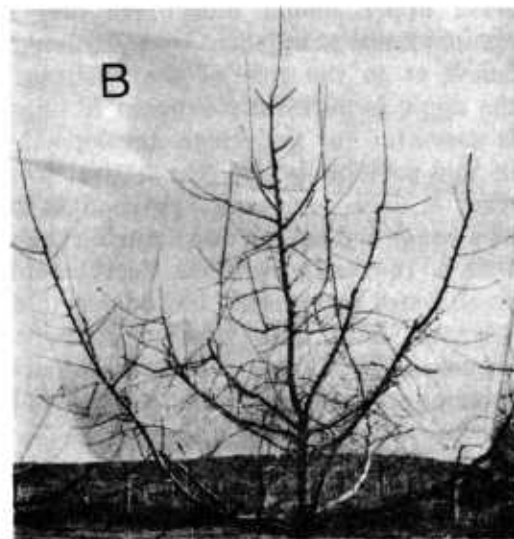
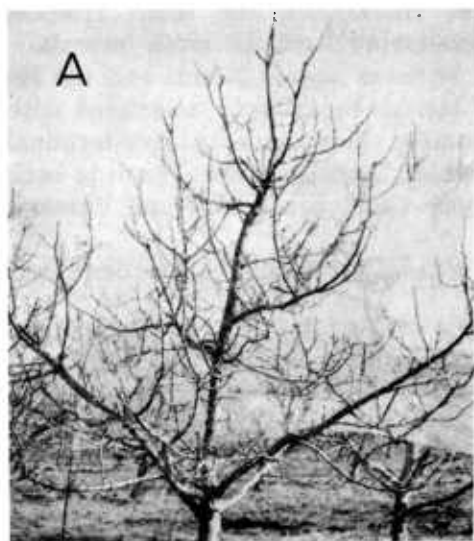


FIGURE 13.—Adequate space is needed between limbs on the central leader. *A*, The wide space between these limbs will be filled with fruiting branches in the mature tree. *B*, Limbs allowed to develop too close together will restrict each others' development. PN-3486/PN-3487

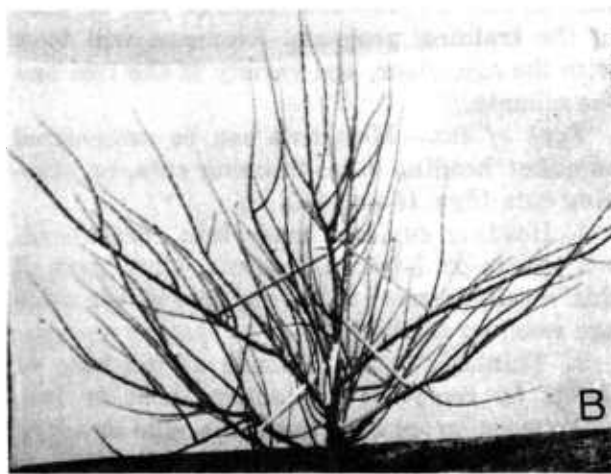
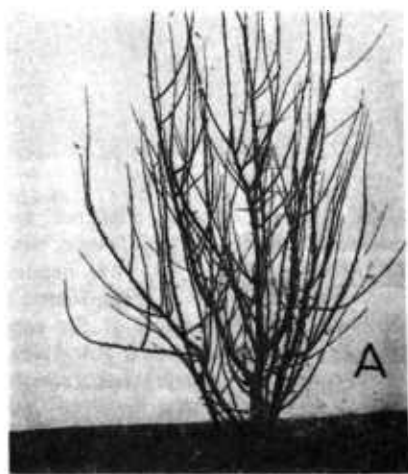


FIGURE 14.—*A*, Spreading untrained trees. Spreading limbs increases their light-intercepting ability and promotes fruitfulness. *B*, Note the great change in this tree resulting from spreading of the limbs. PN-3488/PN-3489



saved by spreading. If strong limbs are allowed to grow upright along the central leader, without spreading, they interfere with the development of additional laterals originating from the central leader.

**Fruit position.**—Limb position is not only important in developing a fruitful tree but also in producing quality fruit. The position in which fruit hangs determines its final quality. Each apple should hang free and not rub against limbs or adjacent trees. By hanging free below or to the side of the fruiting branch, the apple is uniformly exposed to light, which is essential for full color development. Fruit in this position is also less subject to sunburn since it does not change position as the fruit load bends the branch down during the growing season. In windy locations, fruit hanging free on stiffened branches is less susceptible to limb rub and drop than that on upright limber branches. This type of injury is particularly common to spur-type Delicious sports that are not trained properly.

### Principles of Type of Pruning Cut, Season, and Branch-Type Cut

Pruning is involved in any tree-training program. Pruning can be done on different types of branch growth; several types of cuts can be made and in different seasons. The grower should know the response of the tree to these various cuts so that the response can be used in the training program. Response will vary with the age, vigor, and variety of the tree and the climate.

**Type of cut.**—Most cuts can be categorized as either heading cuts, thinning cuts, or stubbing cuts (figs. 15 and 16).

1. Heading cuts are made into current-season shoots or 1-year-old shoots. Only part of this wood is removed, leaving part of the same age wood on the tree.

2. Thinning cuts are made at the base of shoots by removing the entire shoot or into older wood by cutting back to a side shoot or branch. Thinning cuts are often made to direct growth in a different direction when two limbs are competing for the same space.

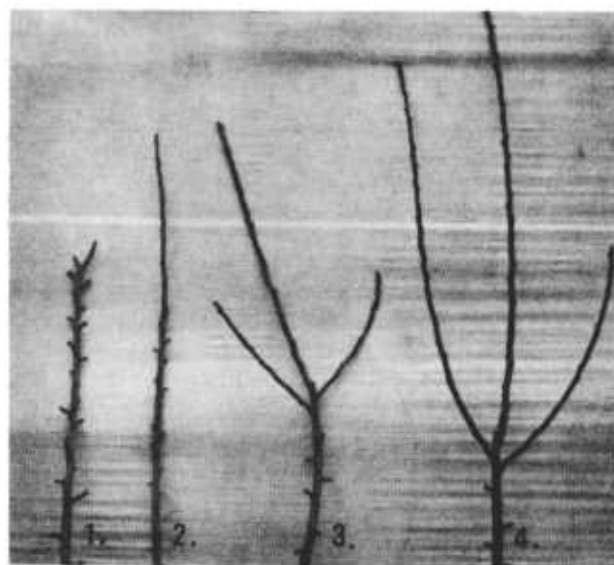
3. Stubbing cuts are those made into older wood simply to reduce the length of the limb

or to begin stiffening formerly unheaded limbs. These cuts differ from thinning cuts in that they are not necessarily made to a dominant side shoot.

4. An alternative to pruning is to not cut at all, leaving the shoot unheaded. Pruning should be avoided or reduced in those sections of the tree where you wish to discourage vegetative growth and to encourage fruiting. This should be practiced mainly on the small fruiting branches developing from the main laterals.

Heading removes terminal buds and the inhibition of lateral bud growth associated with apical dominance. Thinning cuts leave terminal buds that inhibit lateral growth. Heading back leads to more shoot production and development.

**Pruning Season.**—Pruning can be done dur-



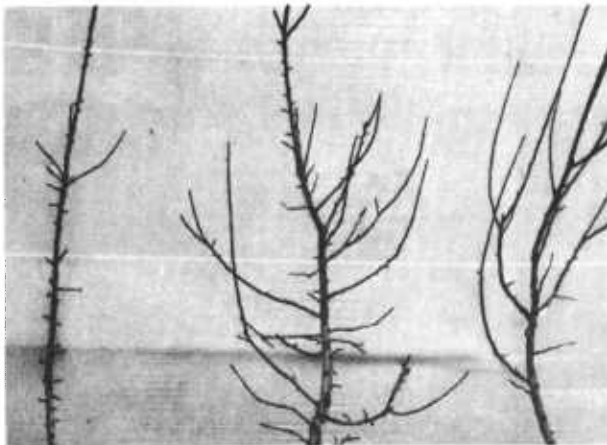
FN-3490

FIGURE 15.—Degree of heading shoots. Pictures are shoots from spur-type trees of equal vigor that were either left unheaded (1 and 2), were headed by cutting off one-quarter of the current season's growth (3), or by cutting off one-half of the current season's growth (4). Shoot No. 1 set a terminal flower bud and had little extension growth. Shoot No. 2 had normal extension growth but failed to develop side shoots. Shoot No. 3 (one-quarter heading) produced good extension growth and two moderate vigor side shoots. Shoot No. 4 produced two rather strong terminal shoots, one of which should be removed in pruning. The more severe the heading cut the greater the stimulation on vegetative extension growth.



ing the growing season or when the tree is dormant. Dormant pruning is the most common. It stimulates growth on the remaining portion of the tree by reducing the number of growing points and removing many terminal buds. In effect, pruning reduces the top while leaving the roots unaltered. At the end of each season, the top (leaf area) and the root are balanced, one supporting the other. By removing part of the tree, the remaining portion has more root support and thus grows more vigorously. Therefore, if growth stimulation is needed, pruning should be done in the dormant season.

Pruning during the growing season can de-vitalize or dwarf trees. Extremely vigorous



PN-3491

**FIGURE 16.**—Degree of heading shoots. The degree of heading shoots determines what type of limb structure develops. The branch on the left was allowed to grow without heading. Many short spurs have developed along this main shoot. Branches such as this bear early but there is only a small potential fruiting area with few replacement spurs, a condition that can lead to alternate bearing. The center limb has been developed by heading all shoots by one-quarter during the years of development. Note the large fruiting area that has developed and the moderate but not too vigorous growth on the side shoots. The first crop will be less than on the unheaded limb but future crops will be larger due to the greater volume of fruiting branches. The limb on the right was developed by cutting all shoot growth in half. Severe cutting like this delays bearing and produces shoots that are too vigorous. This vigorous growth discourages fruiting and produces more shade than is desirable. All three branches are lower horizontal branches developing on central leader trees and are being viewed from above.

trees benefit from summer pruning in that it directs growth or removes unwanted growth during the training period. Early season growth is produced at the expense of stored materials in the tree. After the leaf area has developed, carbohydrates manufactured in the leaves begin to feed back into the storage areas to be used the following season. With summer pruning, leaf area is removed before the feedback process is complete.

Generally, summer pruning is confined to 1-year-old shoots. On shoots headed during the dormant season, two or three vigorous shoots usually develop from the buds immediately below the cut (fig. 17). One or two of these shoots can be removed entirely early in the season to direct the growth into a single shoot. This should be done while shoots are only a few inches long so that little actual leaf area is removed. If the shoots are headed by pinching, rather than complete removal, then regrowth will take place, and the pinching will be of little value.

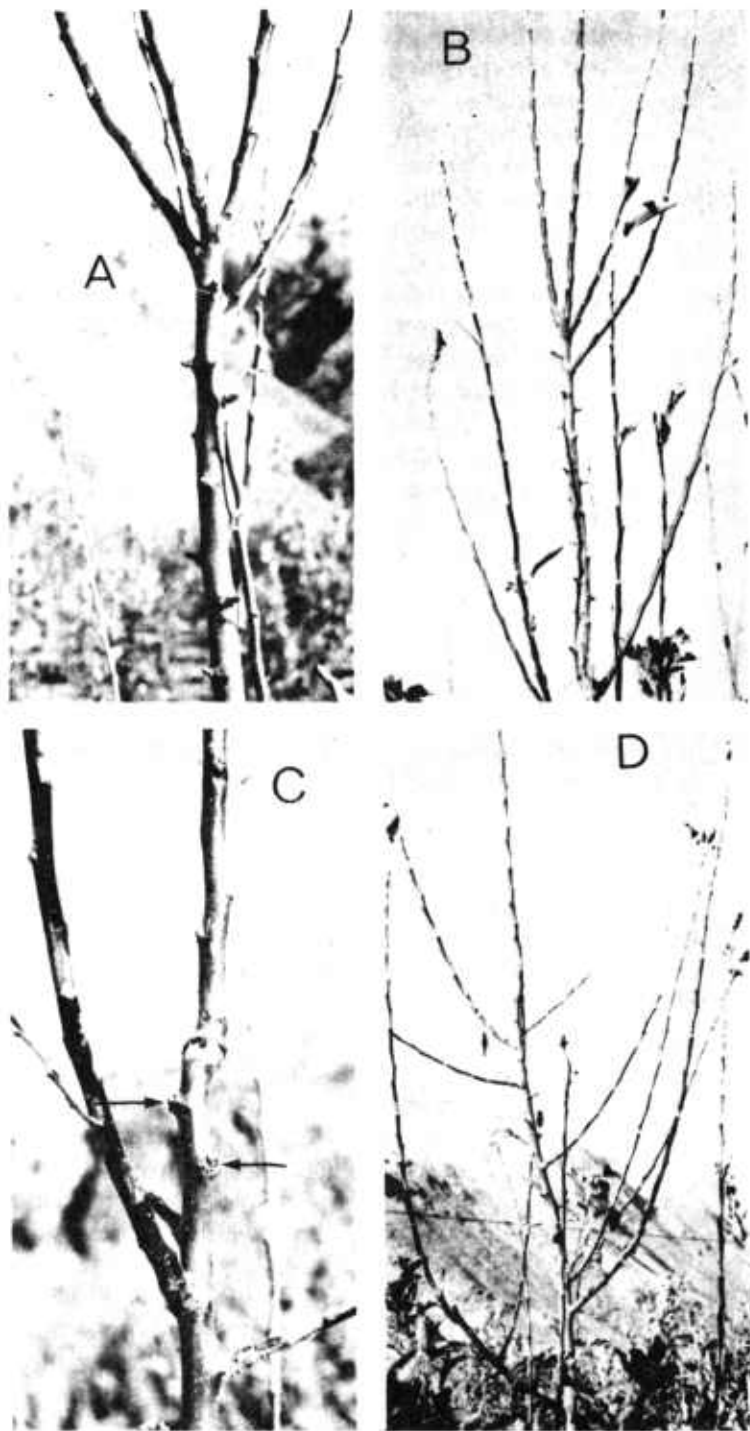
The degree of dwarfing resulting from summer pruning is related to the amount of leaf area removed. The later in the season summer pruning is done, the more leaf area is removed and the greater the dwarfing response (fig. 18). After heading, lateral buds on current season shoots begin to grow and often form a terminal flower bud. Sometimes, this bud will bloom and set fruit the following season, but more often the bloom is late, is poorly developed, and does not set. Nevertheless, summer pruning slows down growth and aids in setting up a fruiting system for the following season provided tree vigor is not too high or the pruning too severe (fig. 19).

The pruning of current season shoots also affects older wood. Summer pruning promotes the development of stronger spurs and a better fruiting system in the older section of the branch. Excessive shoot growth competes for plant nutrients, which delays flowering. Thus, moderate shoot removal tends to favor flower bud development. The best time for this type of summer pruning is at the time of or just before terminal bud formation. Summer pruned spur-type trees grow less than standard types. The dwarfing resulting from summer pruning is

proportional to the percentage of the total leaf area removed and should not be carried to extremes. Weak trees do not respond well to summer pruning and are often stunted.

Occasionally, the normal dormant pruning,

involving some heavy cutting, is delayed because of unfavorable weather shortening the pruning season. This delayed pruning may be considered a type of summer pruning. On older trees, delayed spring pruning causes little difficulty if



PN-3492/PN-3493/PN-3294/PN-3495  
**FIGURE 17.**—Summer shoot removal. Both of the central leaders in these pictures were headed back into a 1-year-old shoot during the previous dormant season. *A*, Note the four strong shoots that developed and, *B*, the complete lack of side shoots on the rest of the 2-year-old section. *C*, Two or three competing shoots were removed (arrows) early in the growing season. *D*, Note the development of lateral branching on the 2-year-old section. It is well to carry out this practice on the central leader and all lateral branches for the first few years in the training program.

it is completed by bloom time. If pruning is delayed beyond this period, it may interfere with the development of flower buds for next year's crop and may even cause excessive fruit drop that year. On young developing trees, delayed pruning is quite dwarfing because a large part of the leaf area is removed. Spur-type trees are severely stunted by this practice.

A lack of development of lateral buds on the previous season's shoots, a condition known as blind wood, is a characteristic of some varieties. During the first year or two, delayed heading will often force shoots from the blind wood area. This should not be carried on beyond the first few years and only should be practiced on very vigorous growing trees.

Summer pruning can accomplish the following: (1) Reduce the vigor of the tree or dwarf it, (2) promote development of side shoots, (3) favor flower bud development, and (4) direct growth into selected shoots.

*Type of branch.*—Shoots, spurs, and older branches can be cut at the time of pruning. Each type of growth should be cut for different reasons.

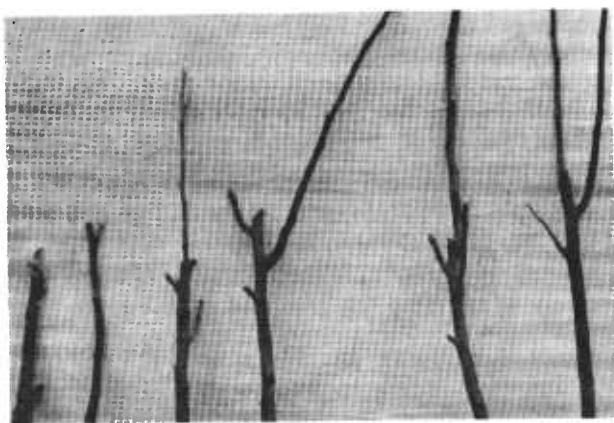
*Shoots* are of two types—current season and 1-year-old. A shoot is considered as a current season shoot until it has lost its leaves and

becomes dormant. After that time, it is considered as a 1-year-old shoot.

In young trees, shoots are used to build the tree structure. In mature trees, they are the source of new fruiting wood. With these shoots we can control and direct the growth of the tree. Although shoots are essential, they can become a problem if handled improperly. In improperly pruned or overvigorous trees, shoots form a shade canopy of "weed growth" that is detrimental to the fruiting area of the tree.

Shoots can be headed, removed entirely, or left untouched. Heading a dormant shoot accomplishes: (1) Vegetative extension growth in the form of two or three vigorous shoots arising from the buds immediately below the cut, (2) branching well down on the shoot below the cut, and (3) thickening and stiffening of the shoot. In contrast, an unheaded shoot usually produces less vegetative extension growth than the previous season, which occurs as a single shoot arising from the terminal bud. The growing terminal has an inhibiting influence on shoot development below it. As a result, less lateral branching occurs on unheaded shoots. Short lateral shoots, often no more than one-fourth of an inch long, develop with terminal fruit buds. In the part of the tree where growth is needed, heading cuts are desirable. When fruiting is desired, shoots should be less severely headed, or remain unheaded. Unheaded branches do not thicken or stiffen as rapidly as headed branches. Since heading cuts stiffen limbs, care should be exercised in the use of these cuts unless some type of physical limb positioning is planned in the training program.

*Spurs* are short fruiting branches. They are characterized by short, irregular, and often branched growth. These are the principal fruiting branches of the trees and remain productive as long as vigor is maintained in the spur. They begin as a short shoot with a terminal flower bud, usually arising laterally from shoots during their second growing season and flowering when the original shoot is 3 years old. A spur produces a fruit cluster and a side shoot. The length of this side shoot is one indication of the vigor of the spur. On most varieties, side shoots of less than one-half inch are a sign of poor vigor and a weak fruiting habit. When this



FN-3496

FIGURE 18.—Summer pruning of risers. The two shoots on the right were pruned in mid-May, resulting in considerable regrowth. The two center shoots were pruned mid-June to late June, producing moderate extension growth and some short spurs. The two shoots on the left were pruned in August, and no shoot growth resulted. It is better to rub these shoots completely out when they are only a few inches long.

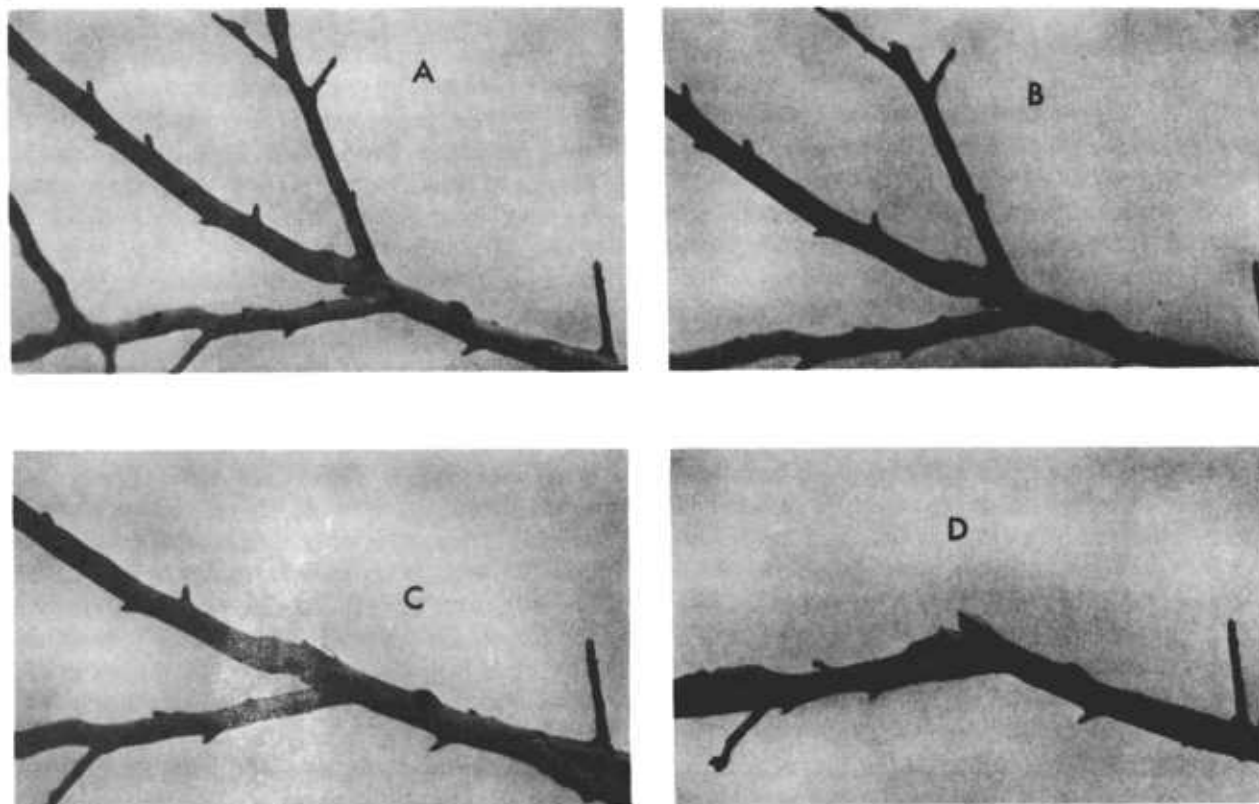


FIGURE 19.—Dormant pruning on risers that were summer pruned. Make this a dwarfing process by reducing the capacity of the riser to carry leaves. *A*, An upright shoot that was summer pruned. *B*, The followup pruning should be a thinning cut back to a weak side shoot. *C*, It is always tempting to remove the entire shoot. This procedure weakens the branch at the point of the cut. *D*, Spreading or fruit load beyond this point often results in breakage.

spur shoot exceeds 12 inches, the tree may be too vigorous because of heavy pruning or fertilization, and poor fruit set may occur. On Golden Delicious, these side shoots tend to be longer than Delicious, often reaching 18 to 24 inches in vigorous trees.

A system that will keep a spur vigorous is necessary for annual cropping. When spurs become weak because of age or shade, they may have to be either entirely or partly removed. Two methods can be used. One is to remove entirely the older pendant spurs and develop new spur growth from shoots. The other method is to use a program of removing pendant portions of spurs each year to stimulate the remaining part of the spur. The last method takes more detail pruning but is rather widely used. Both methods work successfully.

*Older branches* are just what the name implies. They are branches 2 or more years old with lateral shoots, side branches, or spurs. If adequate constructive pruning is not practiced in the early years, corrective cuts may be needed to remove some of these branches entirely to open up the tree and admit more light.

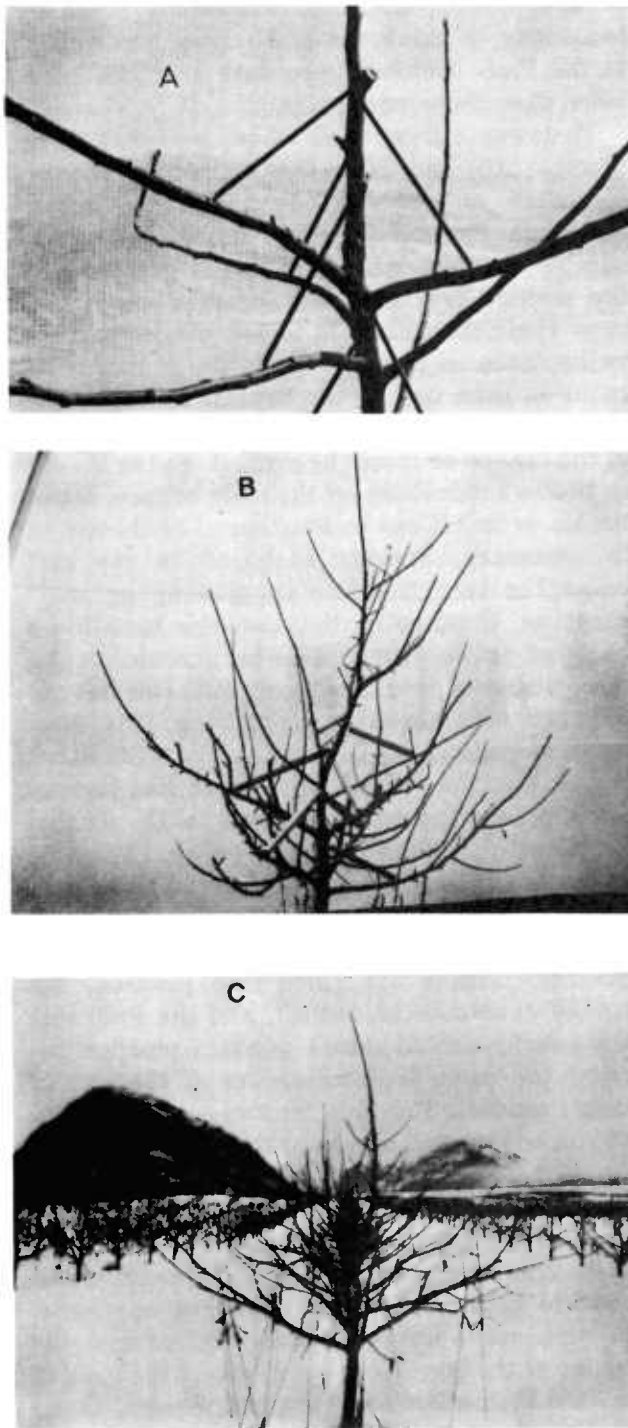
### Limb Positioning

Limb position is the key factor in tree training and in the development and maintenance of fruiting branches. How and when this is done determines its success.

*Methods of limb positioning.*—One can position the limb by using spreaders or braces, by tying the limbs down, by letting the weight of the fruit pull down the branches, or by pruning to outgoing branches.

Spreaders are the most frequently used device for positioning limbs (fig. 20). Short spreaders may consist of sharpened stiff wires or welding rod. For larger ones, various sized wooden sticks with a sharpened nail in each end are useful. Sticks are usually  $\frac{3}{4}$  by  $\frac{3}{4}$  inch or 1 by 1 inch and can be made from 6 inches to 6 feet long. Usually, if a spreader over 3 to 4 feet long is needed, some other method of limb positioning should be used as the spreader would lose its advantage. Spreaders should have a sharp point at each end. Wire spreaders are usually adequate when cut at a sharp angle. Care must be exercised that these cuts are not parallel but perpendicular to each other so that both points are on the same side of the spreader. If points are located on opposite sides of the spreader, they are difficult to place and often slip out. Wire spreaders are usually no more than 10 to 12 inches long. In these lengths, they are generally cheaper than wood. Longer wire spreaders often bend under pressure. Wooden spreaders should be of some softwood, such as pine or Douglas fir, so that the nail can be driven in without splitting. Several types of nails can be used in the end of the wood spreader. A regular box nail can be driven in, and then the head is cut off at a sharp angle forming a point. Another method is to cut the head off the nail first and then press it backwards into the wood with a mechanical or hydraulic press, leaving the sharp point of the nail exposed. A headless nail, called a barbed dowel pin, is convenient to use and can also be pressed into the wood, leaving the point exposed.

Spreaders with a V-notch cut in the end are also used. They are usually 1 to 2 inches wide. The notch is less satisfactory than the nail. It takes longer to cut a notch than to place a nail, so the cost of the spreader may equal that of the spreader with nails. Notched spreaders often blow out or slip along the limb scraping a considerable area of bark. They are also more difficult to position in the tree since they need to be propped against a spur or side branch to prevent slipping. When notched spreaders are used, the notch should be at a wide angle rather



PN-3501/PN-3502/PN-3503

FIGURE 20.—Spreading limbs. Mechanical methods of limb spreading involve the use of some type of spreader such as A, wires, B, wooden sticks with nails in each end, or C, tie-downs connected to various types of anchors.

than a narrow one. The wide-angle notch is less likely to break out and causes less injury to the limb. Notched spreaders scar the bark more than those with nails.

Tiedowns can be used where branches have become too long for the economic use of spreaders, or where wind makes it desirable. Materials for tying down limbs are much cheaper, but the labor involved is greater and the strings are often an inconvenience. The most common method is to use plastic bailer's twine anchored to a hop clip in the ground. The twine is then tied to the branch to hold it in position. Do not tie directly to the main leader of the branch or it will be girdled. Twine should be tied to a side shoot off the main branch. Make the tie so that it can be lengthened or shortened as necessary. Strings anchored in the soil below the tree interfere in mowing or weed spraying. Frequently, these strings have to be removed or cut with a sickle bar mower. Therefore, tiedowns should be used just after the application of a herbicide or mowing. The main value of tiedowns is in temporarily tying down longer branches whose tip growth has become upright, as frequently occurs with Golden Delicious.

Limbs can be spread by use of the fruit load. This method was used to form the trees in most of our older plantings. When the weight of the fruit forces the limbs into position, the spread cannot be controlled, and the limb tips are usually spread into a pendant position because the early fruiting occurs at the end of long branches. For this reason, terminal fruit should be removed on young trees. Fruiting may be used to maintain or slightly increase the spread of the tree, but the initial spread is best accomplished mechanically.

Another mechanical method of spreading has been to prune to outside branches or shoots. In this way, anything growing toward the center of the tree is cut out to direct the growth toward the perimeter of the tree. Several faults are apparent in this method. Making cuts to an outside branch means that you are cutting out the leader of the side branch, delaying the development of the tree. When a strong inside shoot is removed in favor of the outside shoot, the outside shoot takes over the dominant posi-

tion and grows upright. This shoot, in turn, must be cut to an outward growing shoot again and this continues from year to year. The results are an upright shoot that is stiff and vegetative because of the continual heavy cutting without any future chance of spreading either with mechanical means or by the fruit.

*Time of limb positioning.*—Spreading can be done at any season of the year but is best accomplished during the dormant season as a practice accompanying pruning. Often, limbs that are much too crowded can be saved by simply spreading or tying them apart. While the tree is dormant, the basic design of the tree can be studied, and decisions are easier to make concerning the need for spreading. Occasionally, limbs are too stiff to spread when dormant and spreading should be delayed until just before growth begins when the limbs are more flexible.

Although the branches are more limber, spreading during the growing season is slightly more difficult. The leaf area of the tree interferes with good visibility, making the decision difficult on where spreaders should be placed. In addition, the bark is slipping at that time, and unless added care is given to the placement of the spreader, it may slip and rip up the side of the limb. Fruit may also be injured during the spreading operation by being exposed to sunburn. Summer spreading may be done if extremely large limbs are to be spread.

A limb will actually set in the spread position in a very short time during the period of growth when thickening of the branch takes place. A 1- or 2-year-old shoot will set in about a 2-week period anytime from May to mid-July. Older branches may have to be held in position for an entire season or more if the fruit load has not been large enough to assist the spreading operation.

At what tree age should spreading begin, is often asked. In a well-grown tree, branch angle is usually adequate on 1-year-old side shoots and little, if any, spreading is needed. If there are not sufficient branches with good angles the first year, some spreading of the narrower angled branches may be necessary. Generally, these branches should not have been saved in the first place and short wires no more than



4 inches long can be used. Because these 1-year-old laterals have small diameters, the spreaders are more difficult to place and keep in position.

Usually, the best time to spread the lateral is after it is at least 2 or 3 years old. By this time, it has attained good length, its diameter is large enough to easily accommodate the spreader, and it is stiff enough to hold the spreader in place.

*Extent of limb positioning.*—The initial

spreading of the limb should be to about a  $45^\circ$  angle from the central leader (fig. 21). To maintain this angle on the new growth, further spreading will be required. Wider spreading early in the life of the tree may induce shoots to grow from buds on the upper surface of the limb (fig. 22). These shoots compete with the main terminal for growth. When the tree is ready to bear its first heavy crop or when the limbs are long enough to fill the allotted space,

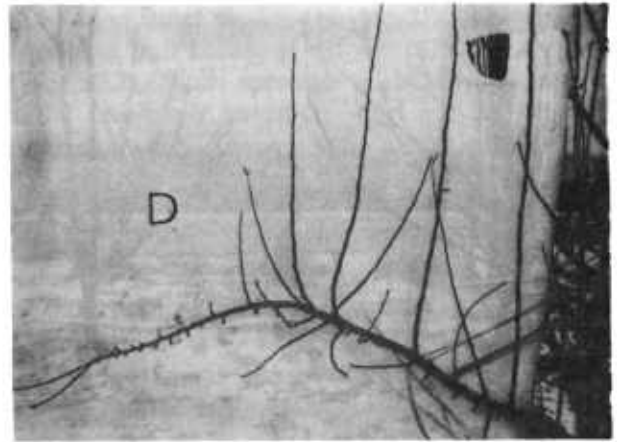
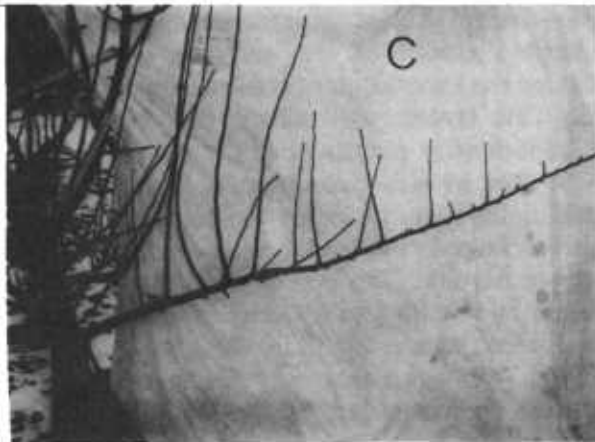
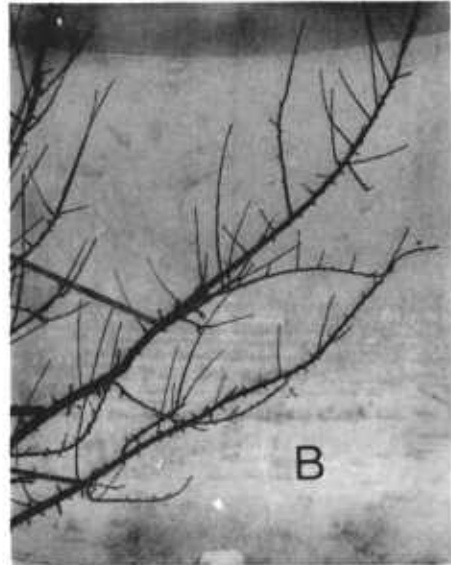


FIGURE 21.—Degree of limb spreading. A, Upright limbs develop few side shoots and remain vegetative at the terminal. B, Limbs spread to  $45^\circ$  seem to be about right for maintaining vegetative extension growth and developing lateral branching. C, Limbs spread below  $45^\circ$  often develop extensive upright growth back on the limb which interferes with further extension growth. D, If the limb is bowed in spreading, so that the terminal is not the highest point on the limb, extension growth stops and a new vigorous shoot develops from the highest point on the limb.

FN-3504/FN-3505/FN-3506/FN-3507



FN-3508

FIGURE 22.—Risers on spread limbs. Risers often develop from the upper surface of the limbs. This heavy upright growth not only dwarfs out the leader but also requires heavy pruning to correct the situation. Complete summer removal as these uprights develop is the best solution.

the limb should be spread further to about a 60° angle from the central leader.

When spreading, the tip of the lateral branch should be maintained as the highest point on that branch. If the branch is bent below the horizontal or if the tip is pulled down putting a bow in the limb, a vigorous shoot will usually develop at the high point of the bow. When this occurs, little new growth develops from the tip.

Spread the branch carefully to avoid splitting it away from the central leader. The smaller the branch, the less danger there is of doing this. Always hold or support the branch near its base and make a rather sharp bend in the branch a short distance out from the central leader. The angle of attachment cannot be improved so try to maintain it in its original position. The sharp bend in the branch serves several purposes. It permits branches with poor angles of attachment to spread; it keeps the rest of the branch straight at an inclined angle without a bow in it; and, possibly most important of all, it is a mild form of scoring the branch that aids in bringing the branch into a

fruitful condition. The cells in the upper part of the branch are stretched and torn apart, and those in the lower part crushed. This temporary constriction aids in fruit set and in flower bud development. This is why more severe spreading should be delayed until the tree is ready for its first large crop.

Some varieties, like Golden Delicious, are more difficult to spread than others due to brittle wood or a tendency to break at the point of attachment to the central leader. To overcome this, the branch should be held solid at its point of attachment with one hand and twisted sideways with the other. This will cause the branch to crack longitudinally, along the length of the branch. The branch is then limber enough to place in any position with a spreader. The longitudinal crack seals rather tightly when released and heals rapidly. This method can be used on older branches as well as young ones. Do not be afraid to twist it too far, just keep bending and it will give.

## TRAINING SYSTEM FOR DEVELOPING CENTRAL LEADER TREES

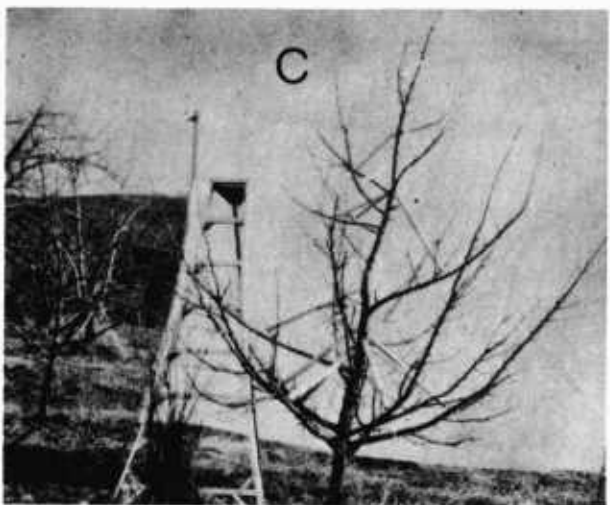
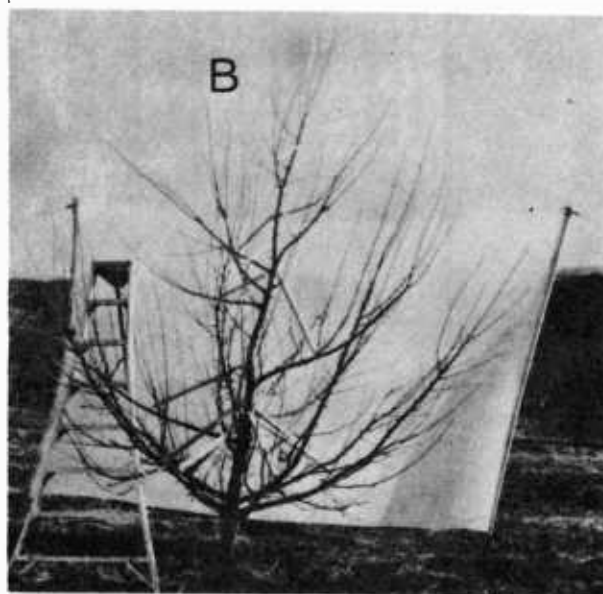
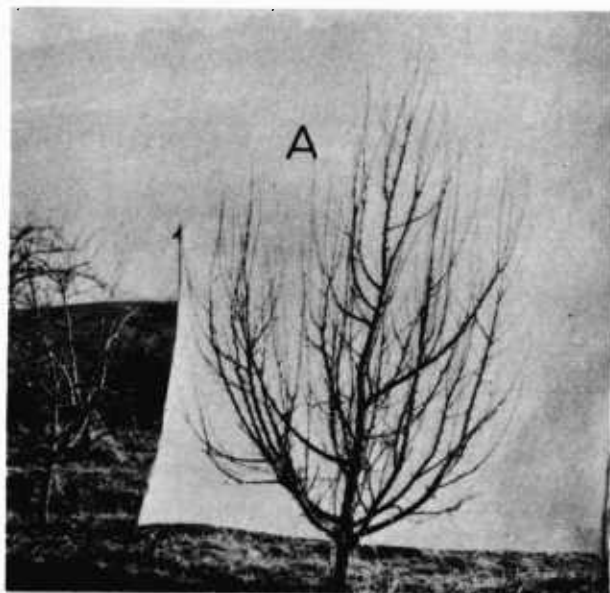
To be successful with high-density plantings, proper pruning, spreading, and shaping of the trees are of utmost importance (fig. 23). The following system of tree training is one that utilizes the knowledge of tree response to pruning. This system will satisfy the requirement of high-density plantings and is simple enough to be used by either the large or small grower. This method can be called the head and spread system for central leader trees and is offered only as a guide. The procedure to be described should be modified to fit local soil and climatic conditions, grower attitude, varieties, and rootstocks. It is suggested only for trees in high-density plantings but can be modified to fit moderate or ultra high-density plantings. It is well suited and should be used on trees dwarfed by either rootstock or spur-type scion varieties.

The general idea is to maintain the tree so there is always a 1-year-old section at the top of the tree that is treated the same regardless of the age of the rest of the tree (fig. 24). Next are 2-year-old, then 3-year-old, 4-year-old, and



older sections or layers. Each is handled differently. This pattern continues until the desired tree height is reached. At that time, the 1-year-old section is still maintained for the life of the tree, but it will be located on top of an older section (fig. 25). Because of poor growth or

lack of lateral branching in a season as the tree develops, it may take more than 1 year to develop a certain section or layer of the tree. Thus, the 2-year-old section may be located on top of the 4- or 5-year-old section rather than the 3-year-old section (fig. 26).



**FIGURE 23.**—A successful tree training and pruning program must be based on several factors. First the training must be constructive using good judgment in limb selection early in the life of the tree. *A*, Even with good limb selection the center of the tree can become overcrowded. *B*, To eliminate the crowded condition limbs should be positioned so that the tree is opened up which results in better exposure to light. Bringing the limbs out of the upright position also encourages fruitfulness. Note the great change in this tree even before pruning. *C*, Following spreading, selective pruning maintains the tree at the desired size and fruitful condition. Note the small amount of pruning leaning against the ladder. *D*, Constructive pruning and training practices result in crops well positioned on the individual limb and throughout the tree. A large percentage of the crop is maintained where it can be picked from the ground.

PN-3509/PN-3510/PN-3511/PN-3512

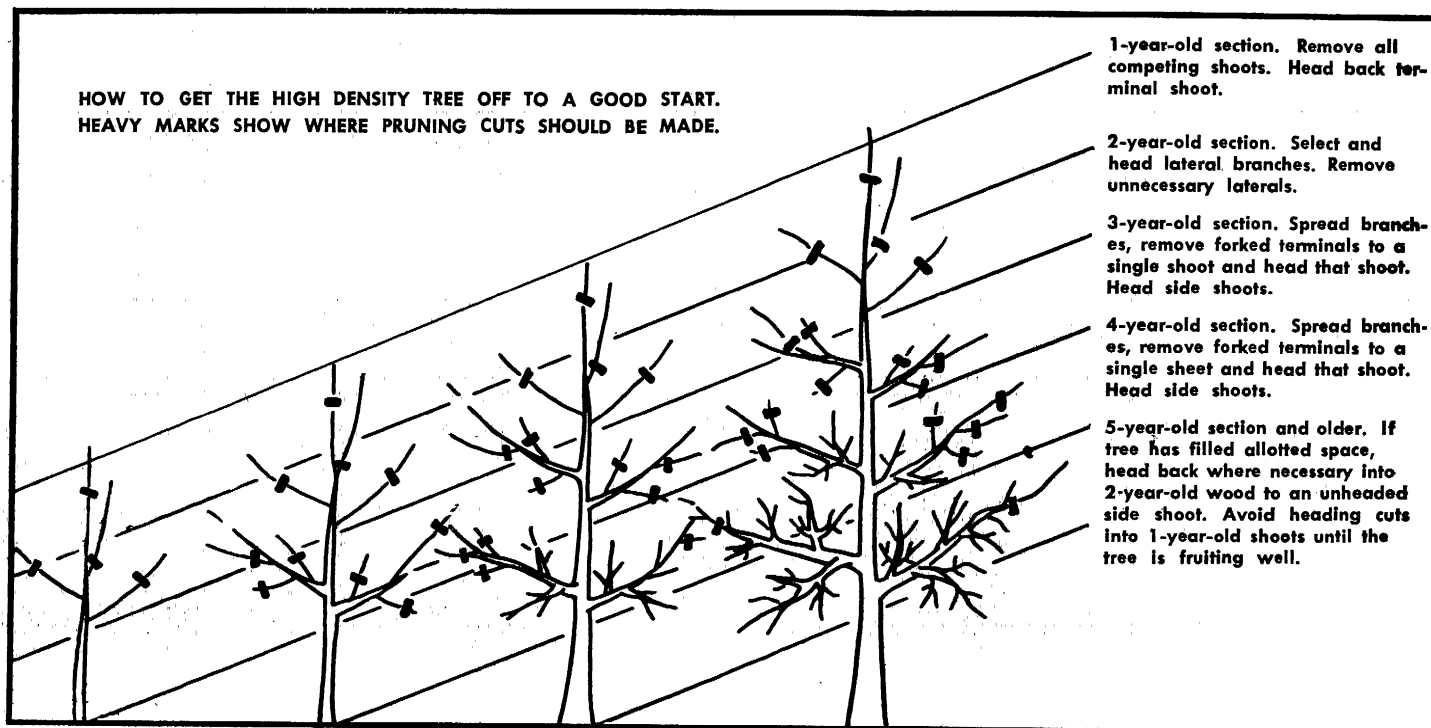


FIGURE 24.—Diagram of age layers.

During the training period, one should apply all the elements of training—limb selection, proper pruning cuts, and limb positioning—to develop the tree into a fruiting unit.

### At Planting Time

At planting time the newly planted tree should be headed. The heading height depends on the desired location of the lowest branches. Heading should be 10 to 12 inches above the desired height of the lowest lateral branch. The lower a tree is headed, the greater the length of the developing shoots will be and the

more dominant the top two or three upright shoots will be. If trees are headed too high, the initial branching will occur rather high, and it will be difficult to develop branches lower at a later date. It is suggested for ease of orchard operation that the lowest branch be no lower than 18 inches above ground level. Therefore, the tree should be headed at 28 to 30 inches. Branches lower than 18 inches often interfere with mowing and chemical weed control. Trees that are headed higher are often slow to develop and in windy locations are subject to wind deformation. Therefore, the more windy the site, the lower the tree should be headed. Where mechanical harvesting is contemplated, 2 feet should be allowed from the ground to the lowest limb.

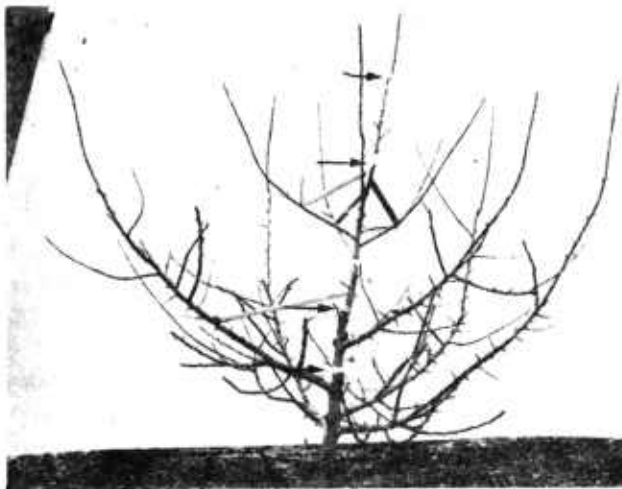
Heading a tree rather hard at planting time promotes the development of many side shoots. As a result, wide crotch angles develop, and a good selection of permanent limbs can be made.

If trees fail to develop properly the first and second year, trunk renewal is an excellent method of getting the tree growing properly. This involves cutting back the tree to a few buds to develop a strong new shoot. If strong trees are used at planting time and good cultural practices are utilized, trunk renewal is not necessary. Spur-type strains often fail to produce shoot growth the first year in the



PN-3513

FIGURE 25.—Terminal shoot on top of central leader. Note how new 1- and 2-year-old sections have developed where central leader was cut back into older wood. The central leader should be maintained in this manner.



PN-3514/PN-3515

FIGURE 26.—Well-developed trees in their 4th year will have 2 (left) to 4 (right) layers of branches. It is not necessary and often not desirable to develop a layer each year but the second layer should be started by the 3d year or productive capacity of the tree may be delayed. Arrows indicate point of heading central leader each year.

ground. As long as leaf size and color are good, do not use trunk renewal. These trees usually grow well during the second season.

Delayed heading has been used by many growers to force lower branches at wide angles. In this method, the tree is headed at planting time about 6 inches higher than the intended heading height. When shoot growth is 2 to 4 inches long it is reheaded about 6 inches below the original cut to a side shoot. This method removes leaf area, which is extremely valuable to the early growth of the tree, and it leaves several branches of equal vigor at the top of the tree. The top one of these branches has to be selected as the central leader. Since the upper branch is not a continuation of the central leader but a side shoot, its dominance is often difficult to maintain. In addition, the central leader develops with a crook in it.

#### During the First Growing Season

During the first growing season a good healthy tree will generally take care of itself if the proper cultural conditions are provided. Several operations, however, can be used to advantage at this time. When conducting these operations, it should be remembered that leaf area this first year is very important to the establishment and future development of the tree. Therefore, as these practices are carried out, be sure to conduct them early enough in the season so as not to remove excessive leaf area.

These operations involve the removal of unnecessary shoot growth to direct growth into the permanent branches and to reduce dormant pruning. The first step is to remove all shoots developing below 18 inches on the main trunk. This should be done early in the season just as the buds begin to break. It is a simple operation of just rubbing off the buds with your hand. This is an essential operation where chemical weed control is to be used and should be done regardless of your later decisions. The second step involves selecting a central leader and three to five permanent lateral branches and removing all other shoots when they are 3 to 6 inches long. Be sure to remove the upper one or two strong shoots that are competing with the central leader. Do not save these for per-

manent branches. All shoots removed at this time should be removed entirely. The lower 18 inches of the main trunk should be rechecked at this time for shoot development.

Remember when conducting this summer training program to do it in such a way that as little leaf area as possible is removed. It is important, however, to wait until shoot growth has developed enough, 3 to 6 inches, to make wise decisions on shoot selection. Where a summer training program has not been carried out, growth is often dominated by the several strong upper shoots competing with the central leader or by branches developing too low on the trunk. It is often necessary to remove all these branches, since they have narrow crotch angles or are in undesirable locations. This heavy, dormant season pruning results in the loss of an entire season's growth.

#### First Dormant Season

The tree at this stage has the new terminal shoot growth (1-year-old section) and the original whip that was planted with lateral side shoots growing from it (the 2-year-old section) (fig. 27).

After selecting the central leader, the 1-year-old section is headed by removing about  $\frac{1}{4}$  to  $\frac{1}{2}$  of the past season's growth. This is necessary to keep it vegetative, to stiffen it in the upright position, and to encourage the development of lateral branches. It is handled just as if it were a newly planted whip. Head it so that new lateral branches will be forced out with adequate space between them and the lower set of laterals. Generally, this should be between 18 and 24 inches. If the central shoot is not long enough to allow this space of 18 to 24 inches, cut it back rather hard so that a strong shoot will develop, which can be headed at an adequate height the following year.

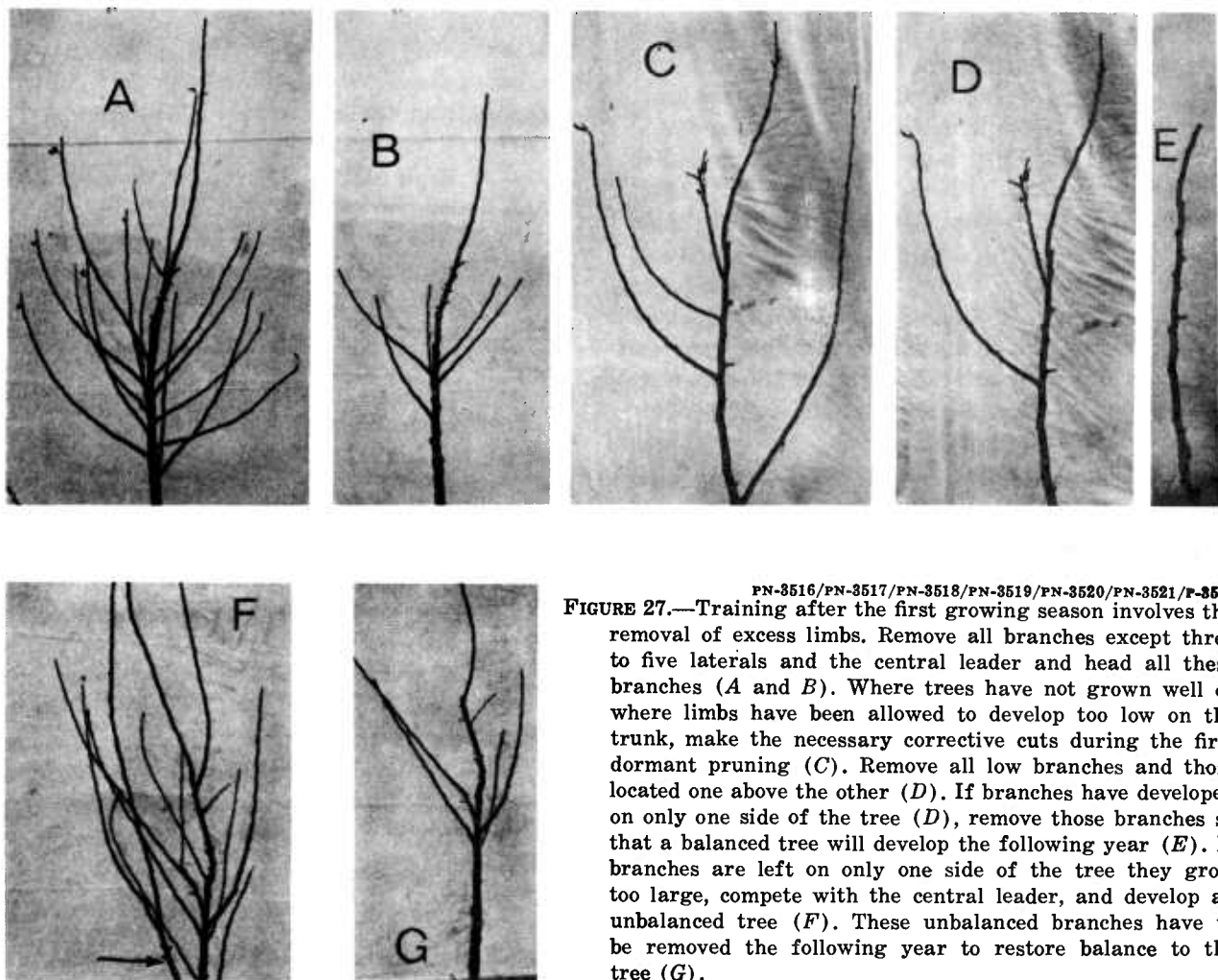
In the 2-year-old section, there may be a number of 1-year-old lateral shoots depending upon the degree of summer training. The uppermost one or two shoots, which compete with the central leader, are removed if this was not done in the summer. The practice here is to remove the strong growth and keep the weak. That is, remove the strong upright shoots competing with the leader and keep the less vigorous more

horizontal lateral shoots. Select no more than five of these lateral shoots to form the framework, and remove the rest of the laterals. The retained laterals are headed by cutting off about one-fourth of the past season's growth. They are headed for the same reasons the central leader is headed, to stiffen and promote terminal and lateral shoot growth. The laterals that are selected should be well distributed and spaced around the main leader. Any excess laterals should be removed now if they were not removed during the summer. The basis of constructive pruning is to remove only 1-year-old or current-season and 1-year-old shoots. The smaller the shoot when removed, the less loss it is to the tree, and future growth can be

directed to the permanent parts of the tree.

If the tree has not produced five good lateral branches, use what is there, provided they are well balanced. If only one lateral shoot has developed, remove it. If it is left on the tree, it often becomes too dominant. It is better to wait a year to get sufficient shoots to develop a well-balanced tree. If only two or three shoots develop and are on opposite sides of the tree, they should be retained; but if they are all on the same side, remove them all and select permanent limbs the next year.

When the first dormant pruning is completed, the tree should consist of the original whip, which is now topped by a 1-year-old shoot. There should be two to five lateral side shoots



PN-3516/PN-3517/PN-3518/PN-3519/PN-3520/PN-3521/P-3522  
**FIGURE 27.**—Training after the first growing season involves the removal of excess limbs. Remove all branches except three to five laterals and the central leader and head all these branches (A and B). Where trees have not grown well or where limbs have been allowed to develop too low on the trunk, make the necessary corrective cuts during the first dormant pruning (C). Remove all low branches and those located one above the other (D). If branches have developed on only one side of the tree (D), remove those branches so that a balanced tree will develop the following year (E). If branches are left on only one side of the tree they grow too large, compete with the central leader, and develop an unbalanced tree (F). These unbalanced branches have to be removed the following year to restore balance to the tree (G).

or, if growth was poor, no side shoots. All these shoots should be headed as described above.

Usually, no spreading is required, but some growers prefer to start spreading a few limbs at this time. Spreading can be used to suppress the growth of a lateral that is too strong. Small wires, 4 to 6 inches long, can be used for spreading at this time.

### Second Growing Season

The tree is still being developed so growth is the goal. Each of the lateral shoots and the central leader, which were headed in the dormant season, will develop two to three vigorous terminal shoots. Only one of these is needed. Usually, they are all allowed to grow and are cut out during the dormant season. It is better, however, to remove these excess shoots early in the season when they are 3 to 6 inches long. Growth is then directed into the permanent branch extension. These shoots can be pulled off very rapidly at this time. Their removal encourages the development of weak side shoots on the branch. In addition to the excess shoots that grow at each shoot tip, extra laterals often develop from the central leader. These laterals may be left for removal during the dormant season, but it is better to remove them during the summer. Summer training as described for the first year is also desirable at this time in the 1-year-old section of the tree. In addition, any shoots arising from the top side of the lateral branches should be removed.

### Second Dormant Season

The tree now consists of 1-, 2-, and 3-year-old sections. The 1- and 2-year-old sections should be handled as previously described. When selecting the laterals on the 2-year-old section, space them an adequate distance above those below. This distance should be no less than about 18 to 30 inches. This seems like a great distance in a young tree, but the space will soon be filled. Such a distance may require that none or very few lateral branches will be selected in that 2-year-old section.

The 3-year-old section now requires some special attention. At this time, some spreading of the branches will be necessary. Less cutting

will be necessary if spreading is done before pruning. Refer to the section on spreading for details of the operation. Spread the branches out from the central leader at about a 45° angle. Care should be exercised not to break the branches at their points of attachment. Hold the branch firmly just above its point of attachment and make a sharp bend beyond that point. Some lateral spreading of the branches may be necessary to separate branches forced together by wind or originally left too close.

Start pruning by removing all excess 1-year-old shoots that have grown from the 3-year-old section of the central leader. Then prune each lateral as if it were a small central leader tree. Select one terminal shoot as the leader and remove any competing shoots. Head the shoot selected as the leader by cutting off about one-quarter of the previous season's growth. Shoots growing from the top of the lateral should be removed if this was not done during the summer. Try to develop a system of shoots originating from the sides rather than the top or bottom of the lateral. All side shoots may be headed to promote further shoot growth. Some varieties produce sufficient side shoots without heading. Heading should only be used to encourage terminal shoot growth and branching. The central leader is the only terminal requiring heading each year. Lateral leaders should only be headed as branching and growth is needed. Heading and excessive pruning delay fruiting.

### Third Growing Season

Vigorous upright shoots sometimes develop from limbs that have been spread. This problem is most severe if the limbs are spread too flat. These shoots should be removed during the summer as they develop. If they are not removed, they often become dominant and dwarf out the central stem growth of the lateral. The removal of these vigorous upright shoots during the dormant season requires a large cut to be made on the upper surface of the limbs. This type of cut heals slowly and weakens the limb. By removing these upright shoots as they develop, more sunlight penetrates into the tree, a smaller cut is required, and the dormant pruning job is reduced. The practice is espe-

cially desirable on overvigorous trees where these uprights are a more severe problem and where the removal of leaf area may help slow down the growth of the tree. These shoots should be removed entirely and not left as a stub. The removal of leaf area will reduce the vigor of the tree the following season. The summer removal of narrow-croched, vigorous, competing shoots on each headed terminal, as described in the section "Second Growing Season," should be continued at this time. This practice reduces the amount of dormant pruning required.

### Third Dormant Season

By this time, the tree is developed and fruiting should be promoted during the next season. Now there are four age groups, 1-, 2-, 3-, and 4-year-old sections of the tree. Fruiting, if any, should be confined to the 4-year-old section.

The 1-, 2-, and 3-year-old sections are handled as described before. Remember to allow adequate space between limbs developing one above the other. As these limbs are developed up the central leader, they will be smaller than the limb below and as a result can be spaced closer together.

The 4-year-old section now has some laterals that have their own 1-, 2-, and 3-year-old sections. Start pruning by removing competing shoots and all strong upright growth that was not summer pruned. A simple rule for the side shoots is to remove the overvigorous ones, head some of those with moderate vigor, and leave the rest of the moderate vigor and weak shoots unheaded.

Some shoots on the 3-year-old section of these laterals were headed the year before and now have side shoots. Now thinning is used rather than heading cuts. Cut these shoots back only where necessary to an unheaded side shoot. Do as little pruning as possible on this section of the tree, and avoid any cuts into 1-year-old shoots.

### Fourth Growing Season

The practices here should be the same as during the third growing season. Summer re-

moval of any upright shoots that are growing out of bounds and singling out each lateral growing point is always helpful, particularly in extremely vigorous trees. Fruit thinning should be practiced so that the limbs are not pulled out of shape. This means to take all fruit off the upper part of the central leader and from the ends of the lateral branches.

### Fourth Dormant Season

The importance of maintaining the central leader as a strong vegetative shoot should be reemphasized at this stage of the pruning program. It is often a temptation to grow a tree too high in the first few years. The lower branches, then, are difficult to develop. Be sure at this time that the central leader has not been allowed to become too high. Lateral branches should be filled in and well distributed along the leader. Check the vigor of the upper and lower portions of the tree. Remember, the idea is to distribute vigor evenly over the whole tree. If the top has become too tall or lower branches have not developed, cut the top back to size. This may require cutting back into 2-year-old or older wood (fig. 25). Because of the central position of the leader, it will rapidly grow a new terminal shoot, and the initial training process starts over again at that level on the 1-year-old shoot.

Before pruning, the limbs should be spread; this may require the relocation of some existing spreader and the addition of some longer spreaders. Place each limb so that it has its own area in which to grow. Space limbs so that a minimum amount of cutting is necessary.

The 1-, 2-, 3-, and 4-year-old sections should be handled as before. Pruning should now be directed more to fruiting than growth. The 5-year-old section will be handled the same as the 4-year-old section. The number of heading cuts should be reduced as the tree reaches this age, even in the younger sections of the tree. If the lateral branches are long enough to fill the allotted space, do not head the terminal shoot. Instead, use a thinning cut to a weaker side or terminal shoot and leave it unheaded. In other words, further growth in that area should be discouraged.



### Beyond the Fourth Year

The same principles can now be carried out each year. Be sure to keep a vegetative terminal shoot on the central leader. To maintain it, a heading cut should be made into 1-year-old wood (fig. 25). This may leave only a single bud to grow. Occasionally, it may be necessary to cut back into older wood to renew the shoot. Heading cuts should be replaced in almost all sections of the tree with thinning cuts. Some headings cuts will be needed to replace fruiting wood where growth has slowed down.

### RENEWING OLD ORCHARDS TO HIGH-DENSITY ORCHARDS

Renewing or replanting old orchards often requires that a new system be used, and the reason for going into a new system must be justified.

The grower should turn the problem of tree loss, which results in a need for orchard renewal, into an opportunity to renew his orchard, using the best strains and most efficient management techniques. When planting in old orchard sites, expect poorer growth than was possible before, a lack of uniformity, nutritional problems, and some size control.

The development of any tree or orchard depends upon the quality of the nursery stock, the growth obtained in the early years, tree training, and tree density. When planting in an old orchard site, special attention should be placed on these factors. Only the best and largest nursery trees should be planted; there is no substitute for a good start. Early growth of the young tree can be assured by using a large volume of new soil in the tree hole, proper fertilization and irrigation, and, above all, good weed control. Old established orchard sod is stiff competition for a young tree. Because the possibility of poor growth exists, special attention should be on the training system to prevent the trees from fruiting too early. Prune for growth rather than fruit until the trees are well established. Be sure to develop an adequate framework before allowing the trees to fruit heavily. Renewing an orchard indicates that production has been lost, therefore, high den-

sity plantings can be used to return the block to a productive unit in as short a time as possible.

Interplanting will continue to be used because of the erratic pattern of tree loss, small acreages, and high prices for fresh market fruit. Many growers will find it desirable to maintain any production they have while renewing their orchard. However, renewing plantings as solid blocks will best utilize the full potential of the new trees planted, even if a block consists of no more than a single row. Where interplanting is used, trees are usually planted among trees in varying stages of decline. Trees in these blocks generally have a great range in age, and this type of replanting only perpetuates this condition. Young trees in these plantings do not receive the detailed care they need. As a result, their full potential is never realized. The early development of interplanted trees is seldom equal to that of trees planted in solid blocks.

The total orchard operation suffers when a poor system of interplanting is used. The grower ends up with an orchard of all ages and sizes of trees. Modification of all cultural practices are required to meet the needs of each individual tree according to its age and size. This greatly reduces the efficiency of the operation. If interplanting must be done, what should the objectives be, and what are some possible courses of action?

Any system of interplanting should be considered as orchard renewal rather than tree replacement. This is particularly true if a large percentage of the trees are missing. With a renewal system in mind, the following factors should be considered: (1) Trees should be planted to develop even-aged blocks. Plant heavily in one section rather than scatter trees all over the orchard. Plant so that all the trees for the new block are planted at one time, even if there are existing trees to be removed at a future date. (2) Plant in such a manner that the new trees can be managed as a block, or at least an entire row. Trees planted in solid blocks are easier to manage according to their needs. (3) Develop a system which will allow existing trees to stay in production while the



new orchard is being developed. However, be careful not to sacrifice the young developing orchard for a few apples on the existing trees. Timely tree removal is essential. (4) Bring the orchard back in production as soon as possible. In general, this means renew the orchard as a high-density planting. If the orchard is in need of replacing, it is probably located where it is vulnerable to some factor such as winter injury and tree loss can be expected to occur again. If this is true, a system of high-density planting will reduce the time out of production due to tree loss. That is, it will be quicker to replace a loss of 50 boxes of production if that production comes from several three- to five-box trees rather than from a few 25- to 50-box trees.

Many systems have been used for orchard renewal. Several of them are described in the following examples, which present most of the basic ideas.

1. Replanting to the Existing Planting Distance. In this system, trees are planted either in the old tree location or within the row between the old trees. This is the easiest system, and if the original planting distance is acceptable, it may have some value. When this system is used in low density plantings, they are slow to come back into full production, and all the problems of large trees at wide spacings are returned. Uneven aged stands develop, and individual tree care may be neglected.

2. Double Row Tree Spacing. In this system, trees are planted both within and between rows. In a 30- by 30-foot planting, the renewed orchard will have rows 15 feet apart with trees within the row 7.5 to 10 feet apart. Placing a row of trees down the center of the old work row will cause some difficulty in management until all the old trees are removed. Advance planning as to methods of size control and training is important since extremely high-density plantings are developed. This system will get the orchard back into production in a hurry, and every other row will be a solid block for ease of management.

3. Straddle Row or Offset Spacing. With this system, the orchard is renewed with three new rows for each two existing rows. Considering

an original spacing of 30 feet between rows, the new spacing becomes 20 feet. To accomplish this, trees are interplanted 10 feet apart in every other existing row. In addition, two rows are planted straddling the alternate row and 10 feet on either side of it to make the 20-foot spacing. This method of straddle-row spacing allows for maximum replanting without tree removal and changes tree density to a more acceptable level. Another modification of this system is to plant two rows of trees straddling each existing row, and with 7½ feet on either side. This results in a 15-foot row spacing. Trees within rows are planted 7½ to 10 feet apart. With either of these systems, adequate work space is maintained, all trees are planted at one time, and a good planting distance is established.

These offset or straddle-row plantings are among the best renewal systems. Even-aged blocks are developed, existing trees can be maintained in production for a few years, and high-density plantings are developed.

4. Complete Block Removal and Replant. This is the best method if the grower has additional acreage to carry him over the development period. This does not mean it is limited to large growers. If block renewal is done on a percentage of acreage basis, the size of the orchard makes little difference. In this method, an entire section of the orchard is removed and replanted at any new desired spacing. This is the only system that gives complete freedom in redesigning the orchard.

These are but a few of the many systems that should be considered. Any interplanting system is difficult to handle and will require more detailed attention than solid blocks. Where existing trees are retained, they should be removed within 2 to 5 years to allow the new orchard to develop properly. The important thing is to manage the trees now being planted so that they become productive units as soon as possible.

Before beginning a renewal program, diagram several new designs on grid paper. Then, stake out a few different designs to see what they look like in the orchard. Time spent planning the renewal planting will be well rewarded.

## SELECTING THE SITE

Since high-density plantings are a more intensive type culture than practiced in the past, great care should be used in selecting the site. The investment in these plantings is high; protect it when selecting the site. Frost, wind, and soil are the main factors to be concerned with.

The small trees used in high-density plantings carry their crop close to the ground. They should not be planted in potential frost pockets. Select sites with good air drainage. Plant rows running with the air drainage. Rows planted across the drainage will block normal air movement resulting in frost pockets.

On some sites, wind has a great influence on tree shape. Trees grown in high-density plantings have a rather specific requirement as to shape and space occupied. Everything possible should be done to overcome the effect of wind. Tying trees, one to the other or to posts, to overcome the wind effect may be necessary.

When tree rows are planted parallel to the prevailing wind, tying from tree to tree without interfering with the work row is easy. Rows planted at right angles to the wind cannot be tied without interfering with the work row.

Trees are usually more fruitful on the downwind side, due to limb position, than on the upwind side. Where rows are at right angles to the wind, one side may be heavily fruited while the other side has only a little crop. Rows parallel with wind fruit more evenly on both sides.

Size-controlling rootstocks have more specific requirements as to soil type than do seedling roots. Avoid planting high-density plantings on extremes of light, dry, heavy, or wet soils. Uneven growth, stunting due to overfruiting, and disease may result from these extreme conditions. As a general rule, the more dwarfing rootstocks should be planted on better soil.

## APPLICATION OF SIZE-CONTROL PRUNING TO EXISTING ORCHARDS OF MODERATE TO STANDARD DENSITY

A situation often encountered is an existing orchard, of standard density, in which the trees are beginning to crowd. These trees do not have adequate built-in size control and have often been allowed to develop freely with no tree training. Pruning can be an effective tool to help control the size and light exposure of these trees, but remember that it is just one tool. In the Pacific Northwest, most of these trees are planted 20 by 20 feet or 10 by 20 feet, which is usually too close unless size-controlling rootstock or spur strains are used. The trees have been started as the old type, conventional, spreading, multileader, open center, or modified leader trees originally developed for a wider spacing. At the wider spacing, trees were allowed to spread to 25 to 40 feet. They now must be confined to a spread of 10 to 20 feet. Often, the grower realizes too late that a different type tree is needed for the closer planting. To correct this situation, heavy pruning is often neces-

sary. The idea of controlling tree size with pruning, whether it is called hold and mold, stub, short, or restrictive pruning, can result in problems due to the inherent vigor of young trees, particularly those on seedling rootstocks. When properly used, on moderate to low vigor trees, the result can be very satisfying.

Before describing some guidelines for this type pruning, tree condition and other factors that influence the results should be considered. The conditions to be considered are tree vigor, branch number and position, annual cropping, and tree size in relation to its final allotted space. A system should be developed that involves a balance between pruning and these conditions.

Severe restrictive pruning should not be initiated until tree vigor can be controlled. This type pruning is not a cure-all for problem trees, especially overvigorous ones. It is only a tool to restrict tree size and maintain production

when tree vigor has been balanced or controlled. Both nitrogen and dormant pruning invigorate trees, and they should, therefore, be used with caution on vigorous trees. Vigor control involves several factors including the elimination of legume cover crops, establishment of grass sod, reduced or balanced nitrogen application, and avoidance of overuse of certain types of pruning cuts and heavy cropping. As the need for heavier pruning develops, control tree vigor before beginning. The key to success is a balance between tree vigor and pruning.

Limb position is extremely important to consider before restrictive pruning is used. In wide-spread trees, upright limbs were allowed to develop for several years. These limbs finally bent over with the fruit load into a horizontal position where further spread was easy to control. In high-density plantings, trees are restricted to a small space and their extension growth must be slowed down before the fruit load is sufficient to bend the limbs down. With all trees, particularly spur-type strains, the stiffening process brought on by restrictive pruning should be delayed until the branches bend down from the fruit load and remain down or until they have been tied or braced down out of the upright position. There is no better way to get a branch where you want it than to put it there physically.

A reliable fruit-bearing pattern is extremely important in controlling tree vigor. Until a crop can be depended upon, any program of severe pruning should be avoided. Depend upon the reduction of vigor brought about by annual cropping to offset the stimulation of increased pruning. Some of the worst situations of overstimulation of vigor have developed where heavy pruning was followed by a crop loss due to frost or other factors. The vigorous conditions that result are difficult to get back into balance.

Restrictive pruning should be started before the tree completely fills its allotted space but not too soon before. Slowing a tree down and stopping its growth is easier than reducing the size of an overextended tree. If the tree becomes overcrowded before restrictive pruning is initiated, the lower portion of the tree will become unfruitful due to excess shade. In addi-

tion, heavy cutting will be required to bring the tree back into bounds, and this will promote even more shade-producing shoot growth.

Before beginning a new pruning method on existing trees, consider the balance between pruning, tree vigor, expected fruit load, and the physical conditions of limb position and tree size.

The first step in size control pruning in existing orchards is to consider limb position and number. Move all limbs out of the upright position. The older the tree or longer the limbs, the more horizontal they should be. Changing the position of major limbs in many larger trees is impossible because of their size. Here, allow several of the main branches to remain upright and select smaller limbs off them to be brought down into the horizontal position. This can be accomplished with spreaders or tie-downs from one limb to another at a height that will not interfere with the orchard operation. These limbs do not have to be spread down all the way to the horizontal, the fruit load will do much of the job once the branches are bent in the right direction.

With the younger trees, 4 to 8 years old, it is often possible to select one centrally located leader to spread the rest of the limbs against. Whether the final tree will be maintained as a central leader or open center tree, it is a good way to start them to establish limb position.

Untrained trees often have an excess number of limbs that must be removed. Extremely crowded conditions within a tree can usually be corrected by spreading the limbs. Therefore, delay limb removal until the limbs have been spread. Spreading can take place horizontally as well as vertically to reduce the crowded condition. The idea of limb spreading is to give each limb a place where it is well exposed to sunlight, where it can carry a crop without limb rub, and where it is accessible to orchard operations. Proper limb position greatly reduces the amount of pruning required. If several limbs need to be removed after spreading, they may be removed all at once or a few may be removed each year over a period of several years. When all the excess limbs are removed at once, the crop will be reduced for a year or

two and extreme vigor may be induced, but final tree development will probably be best. Where limbs are removed over a period of several years, crop loss is less, tree balance can be maintained, and good trees can be developed if the program is followed through. As a rule of thumb, the older the tree the more gradual limb removal should be since older trees will be producing a larger crop that would be lost by excessive limb removal. When several large limbs are removed, pruning on the rest of the tree should be light.

When developing the limbs left on the tree, consider each one individually much as the central leader tree described in an earlier section. Use heading or thinning cuts to encourage growth and branch renewal or fruiting as required. Each limb should be maintained from its point of origin to its tip as a single stem. If the limb has already forked into several branches of equal size, select one as the main stem and begin to reduce the others to fit into their allotted space. Always keep the tip of the limb as the highest point on the limb to maintain the dominance of the central stem. Consider these selected limbs as fruiting spears extending out into the orchard space each with its own area to occupy. Where open center trees are wanted, limbs should be developed as a single layer of fruiting branches on these larger limbs. Where they can be converted to central

leader trees, several layers of smaller limbs may be developed.

One of the characteristics of horizontal limbs is the development of upright shoots (risers) along the top of the limb. If allowed to develop, the risers become strong due to their location, dominate the limb, and soon weaken the branch beyond the location of the riser. Risers should be removed entirely by summer or dormant pruning or headed back leaving 7- to 9-inch stubs. If the heading back procedure is used, it should be done in the summer and must be continued for several years to dwarf the shoot and bring it into a fruiting condition. This is often the best practice since complete removal may encourage the development of more upright shoots the following year. Shoots along the sides of the limbs should be encouraged rather than allowing the upright shoots to develop. These can be developed into fruiting branches that will position the fruit for maximum development of quality. Side branches should always be maintained subordinate to the main stem by cutting to a weak or downward growing side shoot.

Fruiting branches developing from the bottom of the main stem, referred to as pendant limbs, usually produce small, poorly colored fruit. On young trees, these branches may be maintained for several years but should be removed as they show signs of weakening.